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# A COMPUTATIONAL MODEL FOR THREE-DIMENSIONAL INCOMPRESSIBLE SMALL CROSS FLOW WALL JETS

# FINAL REPORT

For The Period June 30, 1976 through June 30, 1977

Contract No. N62269-76-C-0382

Prepared for

Naval Air Development Center Warminster, Pennsylvania 18974 DECEMBER 1978

December 15, 1977

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Dr. Norman D. Malmuth Principal Investigator R. K. Szeto
Co-Investigator

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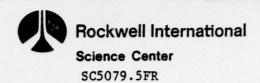
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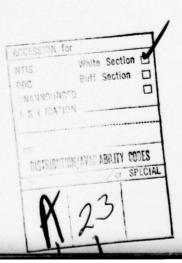
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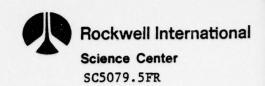
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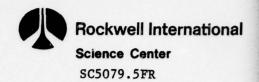
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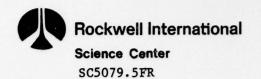
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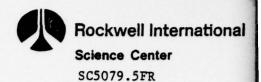
# NOMENCLATURE

ds	differential arc length
s	running arc length along surface, streamwise independent variable
f(η)	normalized stream function, (p. 22)
h <sub>1</sub> ,h <sub>2</sub> ,h <sub>3</sub>	metric coefficients
н	jet height
K	constant in logarithmic spiral equation(4.1), (p. 41)
<sup>K</sup> 1, <sup>K</sup> 2, <sup>K</sup> 3	geodesic curvatures, (p. 10)
L	mean radius radius of curvature, (p. 13)
0,0	order of magnitude symbols, (p. 9)
p	pressure
p	reduced pressure variable
र्वे	velocity vector
Q	initial volume flow from slot
R	Reynolds number based on slot height = $UH/v$
<sup>R</sup> o	initial logarithmic spiral radius
u,v,w	х,у,z components of ф
U	effective mean jet velocity
U <sub>∞</sub>	freestream velocity
x,y,z	orthogonal curvilinear coordinates parallel and perpendicular to wall
X,Y	logarithmic spiral Cartesian set
δ	wall jet thickness
Δ	Laplacian, (p. 8)



# NOMENCLATURE (Cont'd)

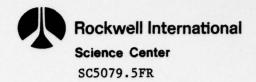
Δ'	Laplacian in x,y
ε	reciprocal of Reynolds number = R <sup>-1</sup>
ε <sub>1</sub> ,ε <sub>2</sub>	eddy viscosities
η	Glauert similarity variable, (p. 22)
θ	polar angle
κ	curvature of wall in x,y plane
ρ	density
ψ	stream function, (p. 22)
ω	coflow velocity ratio = $\mathrm{U}/\mathrm{U}_{\infty}$ for two-dimensional wall jet
ळं	vorticity vector
τ	metric function, (p. 8)
Subscripts	
0	refers to quantities at jet exit
00	refers to quantities infinitely far upstream



#### FOREWORD

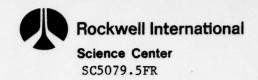
This document describes analytical and computational studies of three-dimensional incompressible laminar and turbulent wall jets in small cross flows. This effort was performed during the period June 30, 1976, to June 30, 1977, and was sponsored by the Naval Air Development Center under Contract No. N62269-76-C-0382.

The technical monitor for this study was Dr. K. A. Green.



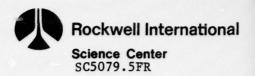
#### ABSTRACT

A computational model based on H. Keller's box scheme has been used to characterize turbulent incompressible wall jets in the small cross flow approximation prototypic of flows over upper-surface-blown and augmenter wings with ejectors employing Coanda wall jets. Submerged (i.e., zero secondary flow velocity) and coflowing cases are considered. An eddy viscosity model was used to simulate the effects of turbulence. Approximate models are identified for flows in which the jet height tends to zero. If the span flow is introduced through a lateral curvature term appearing in the spanwise momentum equation, the effect of the turbulent coupling on the surface pressures, and peak spanwise velocities is weak.



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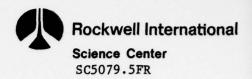
The authors wish to express their appreciation for the valuable comments and review of this report by Drs. K. A. Green, W. D. Murphy, and V. Shankar. Contributions of J. D. Cole relevant to Section 2.5 are also acknowledged.



#### 1.0 INTRODUCTION

Modern naval aircraft can reduce strike force vulnerability by distributing these vehicles over a larger number of ships within the fleet. One way of achieving this allocation is through the attainment of vertical lift-off capability. A technique used to provide vertical lift without oversizing the engine in the cruise mode is the use of thrust augmenting ejectors. With these devices, engine thrust can be enhanced during vertical takeoffs and landings. Obviously, it is desired to achieve the highest thrust augmentation ratio (4) as possible. Various design concepts have been advanced toward obtaining this goal. In the Navy/Rockwell International XFV-12A, for example, an ejector system composed of a centerbody and two Coanda wall jets is currently under development. A central feature of the flow fields produced by this system is three-dimensionality. This has been particularly evident in subscale flow visualization on the Coanda surfaces. It is believed that these flow processes may be important toward  $\phi$  maximization. One way of understanding this relationship is through theoretical modeling which can provide a means of reducing the high cost of powered lift testing. Unfortunately, existing methodology has been limited in the past to two-dimensional flows for the analysis of wall jets and complete ejector systems.

In Ref. 1, a semi-analytical solution for a wall jet over a flat plate is considered. Both the cases of laminar and turbulent flow are treated. Similarity solutions are studied for the laminar case in which the flux of exterior momentum flux is an invariant. For the flat plate case, the existence of this constant does not depend on similarity. With regard to two-dimensional



laminar jets over a curved wall treated in Ref. 2, similarity is necessary to obtain the corresponding invariant. Two-dimensional turbulent wall jets were also considered by Giles, et al., who studied self-preserving behavior for logarithmic spiral profiles. Various workers have studied turbulent processes experimentally in two- and three-dimensional wall jet flows. This effort is exemplified by Refs. 4-7. Coflowing jets which in contrast to the submerged case have the jet embedded in an external inviscid field are of great practical interest. Kruka and Eskinazi have investigated deviations from similitude in such flows as well as merging of the mixing and wall layers.

Three-dimensional turbulent processes have been studied in connection with downstream behavior of non-circular jets over flat plates and are exemplified by Refs. 9 and 10. These investigations have relevance to the prediction of ejector three-dimensional mixing described in Ref. 11.

The mathematical prediction of these flows presents formidable problems. Only the simplest geometries, e.g., flat plate or special wall shapes such as the logarithmic spiral, lead to an ordinary differential equation for a similarity solution. For turbulent flows, with realistic eddy viscosity models, partial differential equations govern the flow field. Modern finite difference methods offer promise of handling these cases. In particular, Dvorak in Ref. 12 treats two-dimensional wall jets over boundaries of large curvature. Computational modeling of three-dimensional generalizations of these flows has up till now been unexplored to the best of our knowledge. This class of flows occurs in connection with taper and sweep effects on lift augmenters and upper-surface-blown wings.



To shed light on the associated flow patterns, a study, "Three-Dimensional Flow of a Wall Jet," was initiated by the Naval Air Development Center to investigate wall jet flows which exemplify typical features of complex propulsive lift applications. The purpose of this study has been to apply modern computational methods to the treatment of three-dimensional wall jets. The following three basic tasks were performed:

- Task 1: Formulate a model to describe a 3-D wall jet in the small cross flow approximation.
- Task 2: Develop a numerical method and computer code to treat a 3-D wall jet.
- Task 3: Parametric studies using computer code.

In Task 3, the streamwise developments of shear stresses, sideslip angles, streamwise, and spanwise velocity profiles have been studied.

This report will summarize the basic results for all three tasks.



#### 2.0 FORMULATION OF THE PROBLEM

## 2.1 Description of Physical System and Assumptions

The configuration shown in Fig. la has formed the basis of this investigation. Depicted is a section of a three-dimensional wing OPCEFO which has a wall jet over its surface ADEF generated by the efflux from the slot ABCD. An intrinsic coordinate system (x,y,z) is arranged so that the slot ABCD is embedded in the surface x = 0, and the wing is the surface y = 0. Surfaces x = constant are normal to the wing and orthogonal to y = constant as shown in Fig. 1b. For simplicity, a cylindrical arrangement is shown with the z direction parallel to generators of the cylinder. However, the formulation to be discussed can be applied to more complicated three-dimensional shapes.

#### 2.2 Incompressible Navier-Stokes Equations

To serve as a framework for subsequent developments, the incompressible Navier-Stokes equations are considered in this section.

Denoting an arc element ds, and the orthogonal curvilinear coordinate system given in Fig. 1a, and the metric coefficients  $h_i$ , i = 1,2,3, ds is given by

$$ds^{2} = h_{1}^{2}dx^{2} + h_{2}^{2}dy^{2} + h_{3}^{2}dz^{2}$$

If u, v, and w are, respectively, the velocity coordinates in the x, y and z directions, then if  $\dot{q}$  = (u,v,w), p = pressure,  $\rho$  = density,

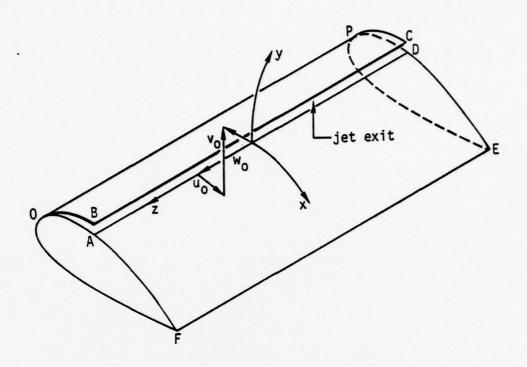


Fig. 1a Geometry of wall jet configuration

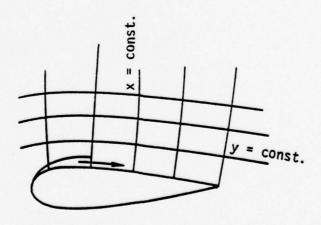
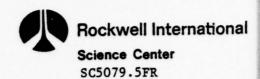


Fig. 1b Intrinsic coordinate system



 $\vec{\omega}$  = vorticity = curl  $\vec{q}$ , then the equations of motion for a laminar flow\* with constant kinematic viscosity  $\nu$  are:

# Continuity

$$div \stackrel{\rightarrow}{q} = 0 \tag{2.1}$$

## Momentum

$$\overrightarrow{q} \times \overrightarrow{w} = \operatorname{grad}\left(\frac{p}{\rho} + \frac{q^2}{2}\right) - v \text{ div grad } \overrightarrow{q}$$
 (2.2)

On taking components, these equations become

#### Continuity

$$(h_2h_3u)_x + (h_3h_1v)_v + (h_1h_2w)_z = 0$$
 (2.3a)

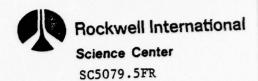
# x Momentum

$$-\frac{v^{2}h_{2}}{h_{1}h_{2}} + \frac{uu_{x}}{h_{1}} + \frac{v(h_{1}u)_{y}}{h_{1}h_{2}} + \frac{w}{h_{1}h_{3}} (uh_{1})_{z} - \frac{w^{2}h_{3}}{h_{1}h_{3}} = v\Delta u - \frac{p_{x}}{h_{1}\rho}$$
 (2.3b)

$$\Delta A \equiv \text{div grad } A \equiv \nabla^2 A = \frac{1}{h_1 h_2 h_3} \left[ \frac{\partial}{\partial x} \left( \frac{h_2 h_3}{h_1} \frac{\partial A}{\partial x} \right) \right. \\ \left. + \frac{\partial}{\partial y} \left( \frac{h_3 h_1}{h_2} \frac{\partial A}{\partial y} \right) + \frac{\partial}{\partial z} \left( \frac{h_1 h_2}{h_3} \frac{\partial A}{\partial z} \right) \right]$$

<sup>\*</sup>Turbulent flows will be considered in Section 2.6

Coordinate variable subscripts indicate partial differentiation with respect to these variables.



#### y Momentum

$$-\frac{\frac{2}{h_{2}h_{3}}}{h_{2}h_{3}}h_{3y} + \frac{vv_{y}}{h_{2}} + \frac{w}{h_{2}h_{3}}(h_{2}v)_{z} + \frac{u}{h_{1}h_{2}}(h_{2}v)_{x} - \frac{u^{2}}{h_{1}h_{2}}h_{1y} = v\Delta v - \frac{p_{y}}{h_{2}\rho}$$
(2.3c)

# z Momentum

$$-\frac{u^{2}}{h_{3}h_{1}}h_{1_{z}} + \frac{ww_{z}}{h_{3}} + \frac{u}{h_{3}h_{1}}(h_{3}w)_{x} + \frac{v}{h_{2}h_{3}}(h_{3}w)_{y} - \frac{v^{2}}{h_{3}h_{2}}h_{2_{z}} = v\Delta w - \frac{p_{z}}{h_{3}\rho}$$
(2.3d)

# 2.3 Small Cross Flow Approximation

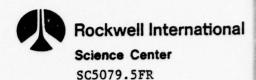
Assuming that w,  $\partial/\partial z << 1$ , Eqs. (2.3) can be simplified to

# Continuity

$$(h_2h_3u)_x + (h_3h_1v)_y = 0$$

#### x Momentum

$$-\frac{{v^2}{h_2}_x}{{h_1}^{h_2}} + \frac{uu}{h_1} + \frac{v(h_1u)_y}{{h_1}^{h_2}} = v\Delta u - \frac{p_x}{h_1\rho}$$



y Momentum

$$\frac{{\rm u}({\rm vh_2})_{\rm x}}{{\rm h_1h_2}} + \frac{{\rm vv_y}}{{\rm h_2}} - \frac{{\rm u}^2}{{\rm h_1h_2}} \; {\rm h_1}_{\rm y} = v \Delta v - \frac{{\rm p_y}}{{\rm h_2}\rho}$$

z Momentum

$$-\frac{u^{2}h_{1_{z}}}{h_{3}h_{1}} + \frac{u}{h_{3}h_{1}} (h_{3}w)_{x} + \frac{v}{h_{2}h_{3}} (h_{3}w)_{y} - \frac{v^{2}}{h_{3}h_{1}} h_{2_{z}} = v\Delta'_{w} - \frac{p_{z}}{h_{3}\rho}$$

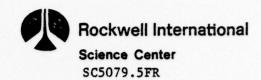
$$\Delta' = \frac{1}{h_{1}h_{2}h_{3}} \left[ \frac{\partial}{\partial x} \left( \frac{h_{2}h_{3}}{h_{1}} \frac{\partial}{\partial x} \right) + \frac{\partial}{\partial y} \left( \frac{h_{3}h_{1}}{h_{2}} \frac{\partial}{\partial y} \right) \right]$$

2.4 Small Cross Flow, Wall Jet Approximation and Order of Magnitude Analysis
Without undue loss of generality, we consider the case for which\*,†

$$\begin{aligned} h_1 &= 1 + \kappa y &, \quad h_2 &= 1 &, \quad h_3 &= 1 + \tau(x, z)y \\ \\ \Delta &= \frac{1}{h_1 h_3} \left[ \frac{\partial}{\partial x} \left( \frac{h_3}{h_1} \frac{\partial}{\partial x} \right) + \frac{\partial}{\partial y} \left( h_3 h_1 \frac{\partial}{\partial y} \right) + \frac{\partial}{\partial z} \left( \frac{h_1}{h_3} \frac{\partial}{\partial z} \right) \right] \\ \\ \Delta' &= \frac{1}{h_1 h_3} \left[ \frac{\partial}{\partial x} \left( \frac{h_3}{h_1} \frac{\partial}{\partial x} \right) + \frac{\partial}{\partial y} \left( h_3 h_1 \frac{\partial}{\partial y} \right) \right] \end{aligned}$$

More general h, 's will be considered in future studies.

<sup>\*</sup>This notation varies in boundary layer analyses. Some authors prefer  $(x,y,z) \rightarrow (h_1,1,h_2)$ .



We consider a wall jet limit involving the jet exit height H becoming small in comparison to the wall radius of curvature at a fixed downstream station x. The jet height  $\delta$  is O(H) as  $H \to 0$ . In addition, y, the normal coordinate to the surface is  $O(\delta)$  in the limit. Furthermore, we assume that metric coefficients  $h_i$  and  $K_i$ , (i = 1,2,3) defined below are O(1). In this limit, the approximate orders of magnitude of the various terms are shown above the equations tabulated below:

#### Continuity

$$u v\delta^{-1}$$

$$(h_3 u)_x + (h_3 h_1 v)_y = 0 (2.4a)$$

(For both terms to balance, v therefore  $\sim \delta u$ )

#### x Momentum

$$\frac{u^{2}}{h_{1}} + \frac{v}{h_{1}} (h_{1}u)_{y} = -\frac{p_{x}}{\rho h_{1}} + v\Delta'u$$
 (2.4b)

(where conclusions from the continuity equation have been used in the ordering)

<sup>\*</sup>Considering two arbitrary functions f(x) and g(x), f = O(g) as  $x \to x$  implies that |f/g| < k as x - x where k is independent of x. The statement f = O(g) implies that  $f/g \to 0$  as  $x \to 0$ .

# y Momentum

$$\frac{u^2 \delta \quad \delta u^2 \quad u^2 \qquad \nu \delta u \delta^{-2}$$

$$\frac{u v_x}{h_1} + v v_y - \frac{\kappa u^2}{h_1} = -\frac{p_y}{\rho} + \nu \Delta v$$
(2.4c)

#### z Momentum

$$u^{2} \quad uw \quad uw \quad \delta uw\delta^{-1} \quad \delta^{2}u^{2} \qquad vw\delta^{-2}$$

$$K_{2}u^{2} + K_{1}uw + \frac{uw_{x}}{h_{1}} + \frac{v(h_{3}w)_{y}}{h_{3}} + K_{3}v^{2} = -\frac{p_{z}}{h_{3}} + v\Delta'w \qquad (2.4d)$$

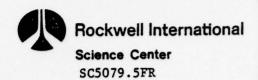
where

$$K_1 = h_{3_x}/h_1h_3$$
,  $-K_2 = h_{1_z}/h_1h_3$ ,  $\frac{\kappa}{1 + \kappa y} = h_{1_y}/h_1$   
 $-K_3 = h_{2_z}/h_3h_1$ 

# 2.5 Finite Momentum Limit for Finite Curvature Walls, (K = O(1))\*-Submerged Wall Jets

To further simplify the foregoing equations, we consider the limit in which  $\rho u^2 \delta$  is fixed as  $\delta \to 0$ . Here, u = O(U), where U is defined as a mean jet exit velocity. Accordingly,  $u = O(\delta^{-1/2})$ . If  $\kappa = O(1)$  as  $\delta \to 0$ ,  $h_1 \doteq 1$ , allowing various terms to be eliminated from the foregoing equations. The ground rules for this process are that at least the frictional term in the

<sup>\*</sup>More complex forms of the equations arise for  $\kappa\delta$  = O(1) but will not be considered in this report.



streamwise momentum equation is retained, and a nontrivial y momentum is desired where the pressure gradient normal to the streamlines balances the centrifugal force. If these guidelines are adopted, the approximate equations become, noting that  $\partial/\partial z = o(\partial/\partial y)$ , and  $\partial/\partial y = O(\delta^{-1})$ :

#### Continuity

$$u_{x} + v_{y} = 0 \tag{2.5a}$$

# x Momentum

$$uu_{x} + vu_{y} = vu_{yy}$$
 (2.5b)

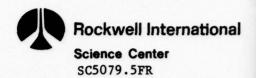
#### y Momentum

$$\rho \kappa u^2 = p_{v} \tag{2.5c}$$

# z Momentum\*

$$\frac{uw}{h_1} + vw_y + K_1 uw + K_2 u^2 = vw_{yy}$$
 (2.5d)

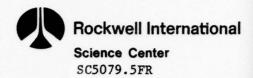
<sup>\*</sup>The K<sub>1</sub> term is negligible for  $h_3 = 1 + \tau(x,z)y$ , but is retained here and in Section 2.8 for more general  $h_3$ 's.



Here, the most interesting case has been retained so that the  $K_2u^2$  term balances other terms in the O(uw) z momentum equation since it is of order  $u^2h_1$  which itself is assumed to be O(uw). For submerged wall jets with  $u \to 0$ , as  $y \to \infty$ , in contrast to curved wall boundary layers, the pressure gradient term  $p_x/\rho h_1$  is negligible in (2.4b), since from (2.4c),  $p = O(\kappa u^2 \delta) = O(1)$ . A similar result is obtained in the finite mass limit  $\rho u \delta = \text{fixed as } \delta \to 0$ . Only for boundary layers or subregions of coflowing wall jet flows with  $\lim_{y\to\infty} u_x \neq 0$  jets implying  $p_x = O(u^2)$  in (2.4b) can the streamwise pressure gradient become important. For the finite momentum limit, inclusion of the friction term in (2.4b) implies  $\delta \sim v^{2/3}$  as  $v \to 0$ . This order of magnitude has been tacitly assumed in the omission of the higher order term  $vv_{yy}$  in (2.5c).

The rationale for the  $\delta$  scaling with  $\nu$  and the disappearance of the  $p_X$  term from the x momentum equation for submerged jets can be more fully understood from three-dimensional generalizations of asymptotic developments to be discussed shortly in connection with two-dimensional flows. Prior to this, we note that for finite mass with  $\rho u \delta$  fixed,  $\delta \sim \nu$  as  $\nu \to 0$ . As will be indicated, other "distinguished limits" are possible in which internal structures such as the wall layer, potential core, and mixing layers can be abstracted.

We conclude this section by noting that the foregoing approximate forms of the equations of motion could be obtained from a formal asymptotic expansion procedure which will be illustrated for two-dimensional curved wall-jets. It is well known that these flows can be divided into a transitional region near the jet exit consisting of a mixing layer, inviscid constant velocity potential

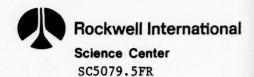


core, and a boundary layer in the vicinity of the wall. The potential core is eaten up by the boundary and mixing layers. Turbulent diffusion results in a merger of these layers at a downstream location. In what follows, we consider the flow in the fully merged zone. As in boundary layers, two different representations can be used to describe the flow structure. An "inner" representation is appropriate to the viscous jet layer near the wall, and an "outer" expansion describes the external inviscid flow. Another option is to develop a uniformly valid asymptotic representation using an optimal set of coordinates developed by Kaplun. 13,14

Denoting the mean velocity at the exit by  $U = Q/\rho H$ , where H is the exit height, and Q is the exit mass flow, the exit momentum is QU. Accordingly, the nondimensional form of Eqs. (2.4) in two dimensions can be obtained by normalizing all velocities with respect to U, the pressure difference from ambient with respect to  $\rho U^2$ , and all lengths with respect to L a mean radius of curvature.\* The resulting dimensionless equations of motion are similar in form to (2.4) except with suitable dimensionless redefinitions of the  $K_1$ ,  $\rho$  and the  $\nu$  coefficients replaced by  $R^{-1}$ , where R = Reynolds number based on  $L = UL/\nu$ .

We now consider appropriate asymptotic representations for the inner viscous layer. Introducing a small parameter  $\varepsilon$  which is the reciprocal of the Reynolds number R, we envision a sequence of flows observed at a fixed x station in which the normalized wall height, H, is allowed to become vanishingly small as  $\varepsilon \to 0$ . If  $\delta(\mathbf{x}; \varepsilon)$  is the characteristic jet height,  $\delta$ 

Note that other normalizing lengths are possible such as the viscous length  $\nu/U$  or the jet height H. The velocities can also be referred to a free stream velocity  $U_{\infty}$  provided the latter is not zero. The selection mode here is advantageous for the arguments that follow.



will scale like H as H  $\rightarrow$  0. To keep the fine structure of the jet layer in view as H  $\rightarrow$  0, we "blow up" the y scale by a factor  $\sigma(\varepsilon)$ , where the functional form  $\sigma(\varepsilon)$  is to be determined. Here,  $\sigma \sim \delta$ . To formalize this, we assert that the y dependence is really a dependence on the strained variable  $\tilde{y} \equiv y/\sigma$ . The most general form of the inner expansion leading to the non-dimensional, laminar two-dimensional specialization of Eqs. (2.5) is

$$u(x,y;\varepsilon) = \varepsilon \sigma^{-2} u_0(x,\tilde{y}) + \varepsilon \sigma^{-1} u_1 + \dots$$
 (2.6a)

$$v(x,y;\varepsilon) = \varepsilon \sigma^{-1} v_0(x,\tilde{y}) + \varepsilon v_1 + \dots$$
 (2.6b)

$$p(x,y;\varepsilon) = \varepsilon^2 \sigma^{-4} p_0(x) + \varepsilon^2 \sigma^{-3} p_1(x,\tilde{y}) + \dots$$
 (2.6c)

for an "inner limit,"  $x,\tilde{y}$  fixed as  $\epsilon \downarrow 0$ . The "gauge function,"  $\sigma$  is determined by matching this solution with the outer inviscid flow.

It should be recognized that for the flat plate boundary layer, since there is no characteristic length in the streamwise direction, the appropriate representations are <u>coordinate</u> expansions for large x rather than for small values of the parameter  $\varepsilon$  of (2.6). Another viewpoint, see, for example, Van Dyke, <sup>16</sup> is to introduce a fictitious normalizing length in the streamwise direction which cancels out in the analysis.

For wall jets, several "distinguished limits" are relevant for the coflow ratio  $\omega \equiv U/U_{\infty}$ , where  $U_{\infty}$  is the freestream velocity in the outer flow. These cases are as follows:

(i) 
$$\omega \rightarrow 0$$

(ii) ω fixed

(iii) 
$$\omega \to \infty$$

(iv) 
$$\omega = \infty$$

as  $\varepsilon \to 0$ . Case (i) is not of interest for propulsive lift applications. Note further that Case (ii) subsumes Case (iv) which corresponds to a submerged jet. If Case (ii) is assumed, then the assertion that u = O(1), uniformly in  $0 \le x \le \infty$ , is plausible based on normalization of this streamwise velocity component with respect to U and matching considerations. Accordingly,  $\varepsilon \sigma^{-2} = 1$  in (2.6a) implying that  $\sigma = \sqrt{\varepsilon}$ . This scaling is also appropriate to conventional boundary layer flows. Substitution of (2.6) into the exact equations and retaining terms of dominant order will give the non-dimensional analog of (2.5a)-(2.5c), for the approximate quantities in (2.6), with an additional pressure gradient term in the axial momentum equation due to the coflow effect. These equations are:

# Continuity

$$u_{o_{X}} + v_{o_{\widetilde{Y}}} = 0$$

#### x Momentum

$$u_0 u_0 + v_0 u_0 = -p'_0(x) + u_0$$

#### y Momentum

$$\kappa u_o^2 = p_{1_{\widetilde{y}}}$$

The longitudinal gradient  $p_0'(x)$  is determined as in conventional boundary layers by matching with the outer flow streamwise pressure gradient which is determined from Bernoulli's equation. Note that the y pressure gradient balancing centrifugal force across the streamlines arises from the second order term  $p_1$  in the pressure expansion (2.6c).

The representation of the outer flow field is obtained from other asymptotic expansions of the flow variables. The appropriate outer variable normal to the body surface is y and the expansions are:

$$u(x,y;\varepsilon) = U_{o}(x,y) + \sqrt{\varepsilon} U_{1}(x,y) + \dots$$

$$v(x,y;\varepsilon) = V_{o}(x,y) + \sqrt{\varepsilon} V_{1}(x,y) + \dots$$

$$p(x,y;\varepsilon) = P_{o}(x,y) + \sqrt{\varepsilon} P_{1}(x,y) + \dots$$

for x,y fixed as  $\varepsilon \to 0$  ("outer limit").

On substitution of these expansions into the exact equations and retaining the dominant terms, the following equations are obtained for the first order quantities:

#### Continuity

$$\mathbf{v_o_x} + (\mathbf{h_1} \mathbf{v_o})_y = 0$$

#### x Momentum

$$U_0U_0 + h_1V_0U_0 + \kappa U_0V_0 = -P_0$$

16



#### y Momentum

$$v_{o}v_{o_{x}} + h_{1}v_{o}v_{o_{y}} - \kappa v_{o}^{2} = -h_{1}P_{o_{y}}$$

To determine the longitudinal pressure gradient in the inner equation and  $\sigma(\epsilon)$ , Bernoulli's equation

$$p + \frac{u^2 + v^2}{2} = \omega^{-2}$$

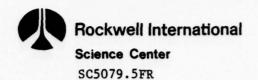
and a matching procedure is used in which the inner and outer solutions are written in a representation appropriate to an intermediate "overlap" domain between inner and outer regions in which the solutions have common validity. For this purpose, the intermediate limit,  $y_{\eta}$  fixed as  $\epsilon \to 0$ , is used in which  $y_{\eta} = y/\eta(\epsilon)$  and the order of  $\eta(\epsilon)$  is between  $\sqrt{\epsilon}$  and unity. The inner and outer expansions are written in terms of  $y_{\eta}$  and are equated to various orders, yielding conditions on the unknown quantities.\*

From the Bernoulli equation and this procedure, the following boundary conditions are obtained

$$V_{O}(x,0) = 0$$
 on  $-\infty \le x \le \infty$ 

$$P_o(x,0) = p_o(x) = \omega^{-2} - U_o^2(x,0)/2$$

<sup>\*</sup>Van Dyke in Ref. 14 uses Lagerstrom's restricted matching principle to obtain similar results for boundary layers without the intermediate variable formalism applied in this section. Cole in Ref. 17 has applied the intermediate variable matching method for a wide class of singular perturbation problems and has derived formulations similar to those described here for boundary layers.



$$\begin{split} &\mathbb{U}_{o}(\mathbf{x},0) = \mathbb{u}_{o}(\mathbf{x},\infty) \equiv \mathbb{u}_{e}(\mathbf{x}) \\ &\mathbb{p}_{1}(\mathbf{x},\widetilde{\mathbf{y}}) = \kappa \widetilde{\mathbf{y}} \mathbb{u}_{e}^{2}(\mathbf{x}) - 2\mathbb{u}_{e}(\mathbf{x}) \mathbb{U}_{1}(\mathbf{x},0) \quad \text{as} \quad \widetilde{\mathbf{y}} \to \infty \\ &\mathbb{V}_{1}(\mathbf{x},0) = \delta^{*}(\mathbf{x}) \quad , \quad \delta^{*} \equiv \int_{0}^{\infty} [\mathbb{u}_{o} - \mathbb{u}_{e}] \mathrm{d}\widetilde{\mathbf{y}} \end{split}$$

The solution procedure is to solve the outer equations with the first of the above boundary conditions. The quantity  $\mathbf{u}_{e}$  is subsequently used with  $\mathbf{p}_{o}$  to solve the inner problem with an initial condition of the form

$$u_0(0,\tilde{y}) = g(\tilde{y})$$

where g is a prescribed function. In this respect, and the turbulence models employed, the wall jet problem differs from the boundary layer formulation. The latter derives its initial conditions from matching with the outer flow, whereas for wall jets, these are specified independently.

The remaining boundary conditions comprise the no-slip conditions,  $u_i(x,0) = v_i(x,0) = 0$  for all i, and the outer boundary conditions for  $p_1$  appearing in the inner y momentum equation.

Note that the quantity  $U_1(x,0)$  must be obtained from the solution of the second order outer problem with  $V_1(x,0)$  expressed in terms of the slope of the displacement thickness  $\delta^{*}(x)$ . Higher approximations are obtained using a similar iteration procedure relevant to this weak viscous interaction problem.



Aside from the differences noted, the foregoing problem strongly resembles a boundary layer formulation, for Cases (ii) and (iv). The latter case is obtained from the former by letting  $\mathbf{u}_e = \mathbf{P}_i = \mathbf{U}_i = \mathbf{V}_i = 0$  for all i. The longitudinal pressure gradient term in the inner x momentum equation is thereby eliminated.

If the velocities are normalized with respect to  $\rm U_{\infty}$  for Case (iii), scalings for the inner variables are obtained which correspond to those derived in the dimensional formulation given in Section 2.5. Formally, the inner equations become in this case

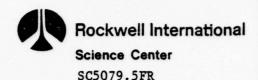
$$u = \varepsilon^{-1/3} u_0(x, \tilde{y}) + \varepsilon^{1/3} u_1 + \dots$$

$$v = \varepsilon^{1/3} v_0 + \varepsilon v_1 + \dots$$

$$p = \varepsilon^{-2/3} p_0(x) + p_1(x, \tilde{y}) + \varepsilon^{2/3} p_2(x, \tilde{y}) + \dots$$

for  $x, \tilde{y} = y/\epsilon^{2/3}$  fixed as  $\epsilon \to 0$ . This will yield identical inner equations to dominant order as for Cases (ii) and (iv). However, it is anticipated that details of the matching will be different. As a check, Bickley's similarity solution for a free jet with transverse momentum flux invariant along the jet exhibits the same  $\epsilon$  scaling shown in the dominant terms of the foregoing expansions.

It is noteworthy that the submerged jet of Case (iv) is degenerate with respect to (iii). This is plausible since normalizations of the latter are non-existent for  $U_{\infty}$  = 0.



# 2.6 Turbulence Assumptions--Eddy Viscosity Models

A prototypic model selected to illustrate the application of a typical eddy viscosity simulation is:

$$\varepsilon_{1} = \varepsilon_{2} = \begin{cases} (0.435y)^{2} \left[ \left| \frac{\partial u}{\partial y} \right|^{2} + \left| \frac{\partial w}{\partial y} \right|^{2} \right]^{1/2} &, y < y^{*} \end{cases}$$

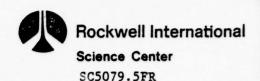
$$\left[ (0.125y_{1})^{2} \left[ \left| \frac{\partial u}{\partial y} \right|^{2} + \left| \frac{\partial w}{\partial y} \right|^{2} \right]^{1/2} &, y \ge y^{*} \end{cases}$$

$$(2.7a)$$

where y<sub>1</sub> is determined by

$$u(y_1) = 0.01$$
  
 $u_y(y_1) < 0$   
 $y^* = \frac{.125}{.635}y$ 

It should be noted that this model provides coupling between the spanwise flow w and the streamwise field u not occurring in the weak cross flow



laminar formulation. From a computational viewpoint, the coupling was suppressed to achieve an efficient algorithm. In our procedure, the finite difference approximation used for (2.7) is such that the discretized momentum equations are effectively decoupled. This was achieved by evaluating  $\partial w/\partial y$  at the previous streamwise station instead of evaluating the average between the present and last computed streamwise station.

Other turbulence models have been proposed for two-dimensional wall jets in which the wall curvature affects the entrainment and eddy viscosity simulation. These can be accommodated by our computational procedure.

# 2.7 Boundary and Initial Conditions

The boundary conditions to be employed are the no-slip conditions at the wall and asymptotic conditions relevant to an "outer" flow field external to the jet. Thus, on the wall y = 0,

$$u(x,0,z) = v(x,0,z) = w(x,0,z) = 0$$
 (2.8a)

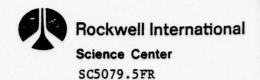
At the edge of the jet,  $y = \infty$ 

$$u(x,\infty,z) = u_{\alpha}(x,z) \tag{2.8b}$$

$$v(x,\infty,z) = v_{\alpha}(x,z) \tag{2.8c}$$

$$w(x,\infty,z) = w_{\alpha}(x,z) \tag{2.8d}$$

$$p(x,\infty,z) = p_{\alpha}(x,z)$$
 (2.8e)



The initial profile must satisfy the compatibility conditions, i.e., a solution of (2.5) or its turbulent counterpart evaluated at x = 0, subject to the appropriate specialization of (2.8). It should be noted that in an incompressible context, the quantity  $p_e$  can be determined from Bernoulli's theorem providing the outer flow is inviscid.

#### 2.8 Formulation in Glauert Variables

To minimize sharp gradients and smooth the computational problem, the governing equations of motion are rewritten in a new set of independent and dependent variables. The Glauert wall-jet transformations given in Ref. 1 are used to change the independent variables (x,y) to  $(s,\eta)^*$ :

$$ds = h_1 dx (2.9a)$$

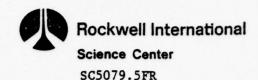
$$\eta = \frac{1}{4} s^{-3/4} y . (2.9b)$$

A new dependent variable  $f(s,\eta)$  is introduced such that

$$\psi = s^{1/4}h_2f(s,n)$$
 , (2.9c)

where  $\psi$  is the stream function satisfying the continuity equation with

The quantities  $(u,v,x,y,\psi)$  are dimensionless, being obtained from the corresponding dimensional variables  $(\bar{u},\bar{v},\bar{x},\bar{y},\psi)$  by writing  $\bar{u}=Uu$ ,  $\bar{v}=Uv$ ,  $\bar{x}=vx/U$ ,  $\bar{y}=vy/U$ ,  $\bar{\psi}=v^2\psi/U$ .



$$\psi_{y} = h_{2}u = h_{2}s^{-1/2}f_{\eta}/4$$

$$\psi_{x} = -h_{1}h_{2}v = h_{1}(s^{1/4}h_{2}f_{s} + s^{-3/4}h_{2}f/4)$$

Furthermore, let p be the reduced pressure given by

$$\tilde{p} = 4s^{1/4}p/\rho \tag{2.9d}$$

Using these transformations, the equations of motion (2.5) simplify to:

## Streamwise Momentum Equation

$$\left( (1 + \epsilon_1) f_{\eta \eta} \right)_{\eta} + \left( 1 + \frac{s}{h_2} \frac{\partial h_2}{\partial s} \right) f f_{\eta \eta} + 2 f_{\eta}^2 = 4 s (f_{\eta} f_{\eta s} - f_s f_{\eta \eta})$$
 (2.10a)

#### Vertical Momentum Equation

$$\tilde{p}_{n} = \kappa f_{n}^{2} \tag{2.10b}$$

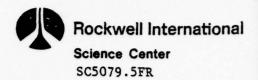
# Spanwise Momentum Equation

$$\left( (1 + \epsilon_2) w_{\eta} \right)_{\eta} + \left( 1 + \frac{s}{h_2} \frac{\partial h_2}{\partial s} \right) f w_{\eta} + 4 K_1 f_{\eta} w + \sqrt{s} K_2 f_{\eta}^2 = 4 s (f_{\eta} w_s - f_s w_{\eta})$$
(2.10c)

In addition, the boundary conditions are given by

#### Boundary Conditions at the Wall, $\eta = 0$

$$f(s,0) = f_n(s,0) = w(s,0) = 0$$
 ,  $s \ge 0$  (2.11a)



## Boundary Condition at Jet Edge

$$f_{\eta}(s,\infty) = \sqrt{s} R(s)$$

$$w(s,\infty) = W(s)$$

$$\tilde{p}(s,\infty) = \tilde{P}(s)$$
(2.11b)

where R and W are arbitrary functions of s obtained from the external flow, and  $\tilde{P}$  can be obtained from Bernoulli's theorem. Consistent with the small cross flow approximation, the dependence on z is absent. It is tacitly assumed in the streamwise momentum equation that  $\tilde{P}'(s) << 1$ , otherwise, the equivalent of the  $-p_X/\rho$  term should be added to the right-hand side of the streamwise momentum equation in accord with a three-dimensional qualitative extension of the matching procedures elucidated in Section 2.5.

### 3.0 NUMERICAL METHODS

### 3.1 The Box Scheme

To solve the wall-jet equations in Section 2.7, an implicit finite difference method (the Box Scheme) developed by H. B. Keller 18 is used. The differential equations are written as a first order system in terms of relabeled dependent variables  $u(s,\eta)$ ,  $v(s,\eta)$ ,  $t(s,\eta)$ :

$$f_{\eta} = u \tag{3.1a}$$

$$u_n = v$$
 (3.1b)

$$\mathbf{w}_{\mathsf{n}} = \mathsf{t} \tag{3.1c}$$

$$\left((1+\varepsilon_1)v\right)_{\eta} = -\left(1+\frac{s}{h_2}\frac{\partial h_2}{\partial s}\right)fv - 2u^2 + 4s(uu_s - f_s v)$$
 (3.1d)

$$\left( (1 + \epsilon_2) t \right)_{\eta} = - \left( 1 + \frac{s}{h_2} \frac{\partial h_2}{\partial s} \right) ft - 4K_1 uw - \sqrt{s} K_2 u^2 + 4s (uw_s - f_s t)$$
 (3.1e)

$$\tilde{p}_{n} = \kappa u^{2} \tag{3.1f}$$

(In passing, we note that the right-hand side of the above system (3.1) does not involve terms that are derivatives of  $\eta$ .)

Now consider any family of meshes  $\begin{cases} k_n | n \\ n = 1 \end{cases}$ ,  $\begin{cases} h_j | j \\ j = 1 \end{cases}$ . From Fig. 2 they satisfy the following

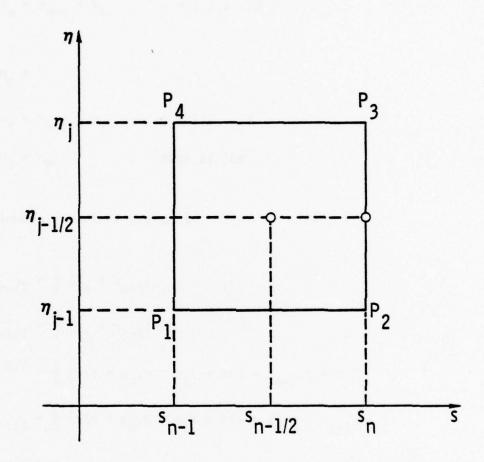


Fig. 2 Mesh configuration

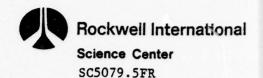


$$\begin{cases} s_{o} = 0 & , \\ s_{n} = s_{n-1} + k_{n} & , & n = 1, 2, ..., N \end{cases}$$

$$\begin{cases} \eta_{o} = 0 & \\ \eta_{j} = \eta_{j-1} + h_{j} & , & j = 1, 2, ..., J \\ \eta_{J} = \eta_{\infty} & , & \text{edge of jet} \end{cases}$$

The following notations are used:

$$\begin{split} \mathbf{s_{n-1/2}} &= \frac{1}{2} \; (\mathbf{s_n} + \mathbf{s_{n-1}}) \quad , \\ \mathbf{n_{j-1/2}} &= \frac{1}{2} \; (\mathbf{n_j} + \mathbf{n_{j-1}}) \quad , \\ \mathbf{z_j^{n-1/2}} &= \frac{1}{2} \; \left( z (\mathbf{s} = \mathbf{s_n}, \mathbf{n} = \mathbf{n_j}) + z (\mathbf{s} = \mathbf{s_{n-1}}, \mathbf{n} = \mathbf{n_j}) \right) \quad , \\ \mathbf{z_{j-1/2}^n} &= \frac{1}{2} \; \left( z (\mathbf{s} = \mathbf{s_n}, \mathbf{n} = \mathbf{n_j}) + z (\mathbf{s} = \mathbf{s_n}, \mathbf{n} = \mathbf{n_{j-1}}) \right) \quad , \\ \mathbf{a_1} &= 1 + \varepsilon_1 \quad , \\ \mathbf{a_2} &= 1 + \varepsilon_2 \quad , \\ \mathbf{P_1} &= \left( \frac{\mathbf{s}}{\mathbf{h_2}} \frac{\partial \mathbf{h_2}}{\partial \mathbf{s}} \right)_{\mathbf{j-1/2}}^{\mathbf{n-1/2}} \quad , \\ \mathbf{P_6} &= \frac{\mathbf{s_{n-1/2}}}{\mathbf{k_n}} \end{split}$$



We now derive the difference equations approximating system (3.1). From Fig. 2, consider box  $P_1P_2P_3P_4$ . Equations (3.1a-c) are approximated by centering about  $(s_n, n_{j-1/2})$  of segment  $P_2P_3$   $(s_n)$  is the streamwise station at which the solution vector (f, u, v, w, t, p) is to be computed):

$$\frac{f_{j}^{n} - f_{j-1}^{n}}{h_{j}} = u_{j-1/2}^{n}$$
(3.3a)

$$\frac{u_{j}^{n} - u_{j-1}^{n}}{h_{i}} = v_{j-1/2}^{n}$$
(3.3b)

$$\frac{w_{j}^{n} - w_{j-1}^{n}}{h_{j}} = t_{j-1/2}^{n}$$
 (3.3c)

Next, Eqs. (3.1d-f) are approximated by centering about  $(s_{n-1/2}, \eta_{j-1/2})$ , the middle of the box  $P_1P_2P_3P_4$ :

$$\frac{(\alpha_{1}v)_{j}^{n} - (\alpha_{1}v)_{j-1}^{n}}{h_{j}} = -(1+P_{1})(fv)_{j-1/2}^{n} - 2(u^{2})_{j-1/2}^{n} + 4P_{6}(f_{j-1/2}^{n-1}v_{j-1/2}^{n} - f_{j-1/2}^{n}v_{j-1/2}^{n-1}) + 4P_{6}((u^{2})_{j-1/2}^{n} - f_{j-1/2}^{n}v_{j-1/2}^{n}) + g_{1}^{n-1}$$
(3.3d)

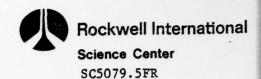
$$\frac{(\alpha_{2}t)_{j}^{n} - (\alpha_{2}t)_{j-1}^{n}}{h_{j}} = -(1+P_{1}) (ft)_{j-1/2}^{n} - 4(K_{1})_{j-1/2}^{n-1/2} (uw)_{j-1/2}^{n} - \sqrt{s}_{n-1/2} (K_{2})_{j-1/2}^{n-1/2} (u^{2})_{j-1/2}^{n}$$

$$+ 4P_{6} \left(w_{j-1/2}^{n} u_{j-1/2}^{n-1} + t_{j-1/2}^{n} f_{j-1/2}^{n-1}\right) + g_{2}^{n-1}$$

$$+ 4P_{6} \left(u_{j-1/2}^{n} w_{j-1/2}^{n} - f_{j-1/2}^{n} t_{j-1/2}^{n}\right)$$

$$+ 4P_{6} \left(u_{j-1/2}^{n} w_{j-1/2}^{n} - f_{j-1/2}^{n} t_{j-1/2}^{n}\right)$$

$$(3.3e)$$



$$\frac{\tilde{p}_{j}^{n} - \tilde{p}_{j-1}^{n}}{h_{j}} = (\kappa)_{j-1/2}^{n-1/2} (u^{2})_{j-1/2}^{n} + g_{3}^{n-1}$$
(3.3f)

where  $g_1^{n-1}$ ,  $g_2^{n-1}$ , and  $g_3^{n-1}$  (the dependent variables in  $g_1$ ,  $g_2$ ,  $g_3$  are evaluated only on the previous streamwise station  $s_{n-1}$ ) are given by

$$g_{1}^{n-1} = -\frac{(\alpha_{1}v)_{j}^{n-1} - (\alpha_{1}v)_{j-1}^{n-1}}{h_{j}} - (1 + P_{1})(fv)_{j-1/2}^{n-1} - 2(u^{2})_{j-1/2}^{n-1} + 4P_{6}(-(u^{2})_{j-1/2}^{n-1} + f_{j-1/2}^{n-1}v_{j-1/2}^{n-1})$$
(3.3d)

$$g_2^{n-1} = -\frac{(\alpha_2 t)_j^{n-1} - (\alpha_2 t)_{j-1}^{n-1}}{h_j} - (1 + P_1)(ft)_{j-1/2}^{n-1} - 4(K_1)_{j-1/2}^{n-1/2}(uw)_{j-1/2}^{n-1}$$

$$-\sqrt{s_{n-1/2}}(K_2)_{j-1/2}^{n-1/2}(u^2)_{j-1/2}^{n-1} + 4P_6\left(-w_{j-1/2}^{n-1}(u_{j-1/2}^n+u_{j-1/2}^{n-1})+t_{j-1/2}^{n-1}(f_{j-1/2}^{n-1}-f_{j-1/2}^n)\right)$$

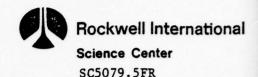
(3.3e)

$$g_3^{n-1} = -\frac{(\tilde{p})_j^{n-1} - \tilde{p}_{j-1}^{n-1}}{h_j} + (\kappa)_{j-1/2}^{n-1/2} (u^2)_{j-1/2}^{n-1} \quad .$$

Equations (3.3a-3.3f) together with (3.3d-f) are to be applied to all  $\eta$ -points, j = 1, 2, ..., J.

The boundary conditions to be applied at  $s = s_n$  are:

wall = 
$$\begin{cases} f_0^n = u_0^n = 0 \\ w_0^n = 0 \end{cases}$$
 (3.4a)



$$\text{jet edge} = \begin{cases}
 f_J^n = F_{n_1}(s_n) \\
 W_J^n = F_{n_2}(s_n) \\
 P_J^n = F_n(s_n)
 \end{cases}
 \tag{3.4c}$$

# 3.2 Solution of the Difference Equations

Assuming solution is known at  $s = s_{n-1}$ , i.e.,  $(f_j^{n-1}, u_j^{n-1}, v_j^{n-1}, w_j^{n-1}, t_j^{n-1}, \tilde{p}_j^{n-1})$  for  $0 \le j \le J$ , we now want to evaluate the solution at  $s = s_n$ . We apply Eqs. (3.3) for  $j = 1, \ldots, J$ . Together with the boundary conditions (3.4), this yields 6\*(J+1) equations for the 6\*(J+1) unknowns  $f_j^n, u_j^n, v_j^n, w_j^n, t_j^n, p_j^n)$ ,  $j = 0, 1, 2, \ldots, J$ .

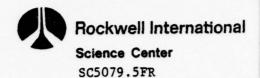
For turbulent wall jets, the streamwise and spanwise momentum equations are coupled through the eddy viscosity of Eqs. (2.7). To handle this computationally, the streamwise momentum equation is solved using the  $\partial w/\partial y$  associated with the previous s step as indicated in Section 2.6. This effectively decouples the streamwise momentum equation from the spanwise momentum equation at any station  $s = s_n$ , reducing the computational time and storage requirement.

With the above approximation, the solution algorithm is then given by:

(i) Solve for 
$$(f_j^n, u_j^n, v_j^n)$$
,  $j = 0,1,2,...,J$ .

(ii) Use (i) to solve for  $(w_j^n, t_j^n)$ ,  $j = 0,1,2,...,J$  (3.5)

(iii) Use (i) to compute  $p_j^n$ ,  $j = 0,1,2,...,J$ .



To treat (i), we must solve a system of 3\*(J+1) nonlinear equations. (The equations are  $(3.3a,b,d)_{j=1}^J$  and (3.4a,c).) Then, assuming (f,u,v) is successfully computed at  $s=s_n$ , (ii) and (iii) involves only systems of linear equations. Thus, the major bulk of computational time is in (i).

We note that the difference equations (3.3) for the variables  $(f_j^n, u_j^n, v_j^n, v_j^n, v_j^n, p_j^n)$  for  $j = 0, 1, 2, \ldots, J$  and  $s = s_n$  can be viewed as the solution to two-point boundary value problems of systems of linear or non-linear ordinary differential equations, with the independent variable being  $\eta$ . Thus (i) now can be viewed as solution to:

$$\frac{\mathrm{df}}{\mathrm{dn}} = \mathbf{u} \tag{3.6a}$$

$$\frac{d\mathbf{u}}{d\mathbf{n}} = \mathbf{v} \tag{3.6b}$$

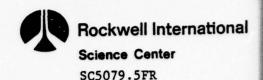
$$\frac{d(\alpha, v)}{d\eta} = -(1 + P_1)fv - 2u^2 + 4P_6(u^2 - fv) + g_1(\eta)$$
 (3.6c)

with boundary conditions

$$f(0) = u(0) = 0$$
 (3.6d)

$$u(\infty) = constant$$
 (3.6e)

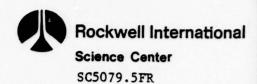
we have deliberately suppressed the dependence of s in  $P_1$ ,  $P_6$ ,  $g_1$ , and the constant in (3.6e). However, they do change as we march downstream.



The theory of numerical solution to two-point boundary value problems for ordinary differential equations can be found in Refs. 19 and 20. We shall only outline the procedure here.

The nonlinear system of equations for the unknown  $U \equiv (f_j^n, u_j^n, v_j^n)_{j=0}^J$  are to be solved by Newton's method. Specifically, we define  $\Phi(U)$ , (suppressing the s-dependence in (f, u, v) again),

$$0 = \phi \equiv \begin{bmatrix} \frac{f_0}{u_0} & \frac{v_0 + u_1}{h_1} & \frac{v_0 + u_1}{2} \\ \frac{u_1 - u_0}{h_1} & -\frac{v_0 + v_1}{2} \\ \frac{\alpha_1 v_1 - \alpha_0 v_0}{h_1} & + (1 + P_1) \left(\frac{f_0 + f_1}{2}\right) \left(\frac{v_0 + v_1}{2}\right) + 2 \left(\frac{u_0 + u_1}{2}\right)^2 - 4P_6 \left\{ \left(\frac{u_0 + u_1}{2}\right)^2 - \left(\frac{f_0 + f_1}{2}\right) \left(\frac{v_0 + v_1}{2}\right) \right\} - g_1 (n_{1/2}) \\ \vdots & \vdots & \vdots & \vdots \\ \frac{f_J - f_{J-1}}{h_J} & -\frac{u_{J-1} + u_J}{2} \\ \frac{u_J - u_{J-1}}{h_J} & -\frac{v_{J-1} + v_J}{2} \\ \frac{\alpha_J v_J - \alpha_{J-1} v_{J-1}}{h_J} + (1 + P_1) \left(\frac{f_{J-1} + f_J}{2}\right) \left(\frac{u_{J-1} + u_J}{2}\right) + 2 \left(\frac{u_{J-1} + u_J}{2}\right)^2 - 4P_6 \left(\left(\frac{u_{J-1} + u_J}{2}\right)^2 - \left(\frac{f_{J-1} + f_J}{2}\right) \left(\frac{v_{J-1} + u_J}{2}\right) \right) - g_1 (n_{J-1/2}) \\ u_J - constant \end{aligned}$$



Let the initial iterate  $\underline{\mathbb{U}}^{(0)}$  be the solution at the previous streamwise station  $s_{n-1}$ . Then, Newton's method\* gives

$$\frac{\partial \Phi}{\partial \overline{y}}^{(\nu-1)} \delta \overline{y}^{(\nu-1)} = -\Phi(\overline{y}^{(\nu-1)}) , \quad \nu \geq 1$$
 (3.8a)

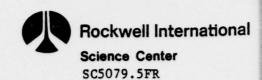
$$y^{(\nu)} = y^{(\nu-1)} + \delta y^{(\nu-1)}$$
 ,  $\nu \ge 1$  (3.8b)

Method is said to have converged at the Kth iteration when

$$\| \delta y^{(K-1)} \| \le \text{prescribed error tolerance}$$
 (3.9)

The Jacobian matrix  $\partial \Phi/\partial U$  in (3.8a) has a very nice structure, a consequence of the centered-Euler method in approximating (3.6)

When  $\alpha_K$  depends on  $U_\ell$ ,  $\ell$  ‡ K-1,K, as most all eddy viscosity models do, then we do not have Newton's method strictly speaking, because we avoid terms  $[(\partial \alpha_K/\partial u)\delta u]v$  and  $[(\partial \alpha_K/\partial v)\delta v]v$ .



where  $\mathcal{L}_{K}$ ,  $R_{K}$  are (3×3) matrices, K = 1, 2, ..., J, are given by:

$$\mathcal{L}_{K} \equiv \begin{bmatrix} -\frac{1}{h_{K}} & -\frac{1}{2} & 0 \\ 0 & -\frac{1}{h_{K}} & -\frac{1}{2} \\ -\beta_{1}^{K} & -\beta_{2}^{K} & -\frac{\alpha_{K-1}}{h_{K}} - \beta_{3}^{K} \end{bmatrix} , \qquad (3.11a)$$

$$R_{K} \equiv \begin{bmatrix} +\frac{1}{h_{K}} & \frac{1}{2} & 0 \\ 0 & +\frac{1}{h_{K}} & \frac{1}{2} \\ -\beta_{1}^{K} & -\beta_{2}^{K} & +\frac{\alpha_{K-1}}{h_{K}} - \beta_{3}^{K} \end{bmatrix} , \qquad (3.11b)$$

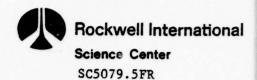
with

$$\beta_{1}^{K} = -\frac{1}{2} \left\{ (1+P_{1})v_{K-1/2} + 4P_{6} \frac{1}{2} v_{K-1/2} \right\} ,$$

$$\beta_{2}^{K} = \frac{1}{2} \left\{ -2u_{K-1/2} + 4P_{6}u_{K-1/2} \right\} ,$$

$$\beta_{3}^{K} = -\frac{1}{2} \left\{ (1+P_{1})f_{K-1/2} + 4P_{6}f_{K-1/2} \right\}$$
(3.12)

The first two rows in (3.10) are contributions from boundary conditions at the wall, with the last row from the jet edge.  $\partial \Phi/\partial \Psi$  can be further partitioned into a block tridiagonal matrix  $[B_iA_iC_i]$ , where



$$B_{i} = \begin{bmatrix} x & x & x \\ x & x & x \\ 0 & 0 & 0 \end{bmatrix} , \quad i \ge 1$$
 (3.13a)

$$A_{i} = \begin{bmatrix} x & x & x \\ x & x & x \\ x & x & x \end{bmatrix} , \quad i \ge 1$$
 (3.13b)

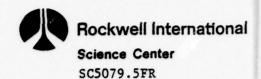
$$C_{i} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ x & x & x \end{bmatrix} , \quad i \ge 1$$
 (3.13e)

Before we go to the next section to describe an algorithm for solving such a matrix system, we want to comment on the solution procedure for (ii) and (iii) of (3.5). As remarked earlier, since (f,u,v) are now known at  $s=s_n$ , the equations for  $w_j^n, t_j^n$ , j=0,1,2,...,J can be viewed as the difference approximation to the <u>linear</u> two-point boundary value problem in <u>one</u> independent variable  $\eta$  of the form

$$\frac{dZ}{dn} = A(n)Z + g(n) \tag{3.14a}$$

$$B_0 Z(0) = 0$$
 (3.14b)

$$B_1 Z(\eta_{\infty}) = \text{constant}$$
 (3.14c)



with  $Z = (w,t)^T$ , A has coefficients (f,u,v) and  $g = (0,g_2)$ , the system of linear equations can again be partitioned into the form

$$Az_h = b_h$$

where  $\mathbb{A}$  is a block tridiagonal matrix,  $\mathbf{Z}_h$  and  $\mathbf{b}_h$  are given by

The computation of (iii) is simply the centered-Euler integration of

$$\tilde{p}(\eta_{K}) = \tilde{p}(\infty) - \int_{\eta_{K}}^{\infty} \kappa u^{2}(\tau) d\tau$$
.



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## 3.3 Block Tridiagonal Solver

In this section we describe the solution to

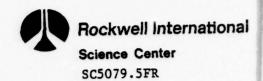
$$\mathbb{A} \times = \mathbb{b} \tag{3.15}$$

where

$$\mathbb{A} \equiv \begin{bmatrix} A_1 & C_1 & & & & & \\ B_2 & A_2 & C_2 & & 0 & & \\ & \ddots & \ddots & \ddots & & \\ & & B_{J-1} & A_{J-1} & C_{J-1} & & \\ 0 & & B_J & A_J \end{bmatrix} \equiv [B_i, A_i, C_i]$$
 (3.16)

$$\begin{bmatrix}
x_{1,1} \\
x_{2,1} \\
x_{3,1} \\
x_{1,2} \\
x_{2,2} \\
x_{3,2} \\
\vdots \\
\vdots \\
x_{1,J} \\
x_{2,J} \\
x_{3,J}
\end{bmatrix}$$

$$\begin{bmatrix}
b_{1,1} \\
b_{2,1} \\
b_{3,1} \\
b_{1,2} \\
b_{2,2} \\
b_{3,2} \\
\vdots \\
b_{1,J} \\
b_{2,J} \\
\vdots \\
b_{n,J}
\end{bmatrix}$$
(3.17)



and  $A_K$ ,  $B_K$ ,  $C_K$  are matrices of order n, K = 1, ..., J.

A can be decomposed into the form

$$A = Lu \equiv [\beta_i \quad I \quad 0] * [0 \quad \alpha_i \quad C_i]$$
 (3.18)

where

$$\alpha_{1} = A_{1} , \qquad (3.19a)$$

$$\begin{cases} \beta_{i}\alpha_{i-1} = B_{i} , & i = 2,3,...,J \\ \alpha_{i} = A_{i} - \beta_{i}C_{i-1} , & i = 2,3,...,J \end{cases}$$

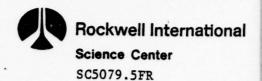
$$(3.19a)$$

Here matrices  $\alpha_{i}$  in turn are decomposed into the form:

$$\alpha_i = p_i \ell_i u_i q_i \tag{3.20}$$

where  $p_i$ ,  $q_i$  are permutation matrices for row-and-column pivoting.  $l_i$  and  $u_i$  are lower and upper triangular matrices. It is important to have an accurate LU-factorization of  $\alpha_i$  because they are used in solving both  $b_{i+1}$  and  $x_i$ . Here we use a mixed pivoting strategy. During the Kth stage of Gaussian elimination, the pivot  $a_{kk}^{(K)}$  is chosen to satisfy

$$|a_{kk}^{(K)}| \ge |a_{k,\ell}^{(K)}|$$
 ,  $|a_{\ell,k}^{(K)}|$   $\ell \ge k$  . (3.21)



This mixed pivoting is much better than the partial column pivoting or partial row pivoting. If  $\varepsilon_{im}$  is the round-off error using the mixed pivoting strategy, and if  $\varepsilon_{ip}$  is the round-off error using either partial column or partial row pivoting strategy, then it can be easily shown that

$$\|\varepsilon_{in}\| \ge \|\varepsilon_{im}\|$$
 (3.22)

The solution of  $\beta_i$  from Eq. (3.19b) can be easily carried out. Assuming there are p rows of  $B_i$  with at least one non-zero element on that row, then the solution of  $\beta_i$  corresponds to inverting the following

$$\tilde{\mathbf{u}}_{\mathbf{i-1}}^{\mathbf{T}} \mathbf{y}_{\mathbf{K}} = \mathbf{B}_{\mathbf{i},\mathbf{K}}^{\mathbf{T}} 
\tilde{\mathbf{x}}_{\mathbf{i-1}}^{\mathbf{T}} \mathbf{g}_{\mathbf{K}}^{\mathbf{T}} = \mathbf{y}_{\mathbf{K}}$$

$$\mathbf{K} = 1, 2, \dots, p \qquad (3.23)$$

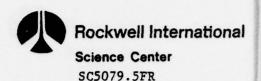
where  $\tilde{\ell}_{i-1}$ ,  $\tilde{u}_{i-1}$  are lower and upper triangular matrices of size n. We further note the zero structure (as in (3.13a)) is preserved under such a decomposition scheme. This avoids unnecessary storage space requirements.

Now assume (3.19) has been performed, then to solve x, we merely have to solve

$$\mathcal{L}_{Z} = b \tag{3.24}$$

$$\mathbf{U}_{\mathbf{x}} = \mathbf{z} \tag{3.25}$$

where  $z \equiv (z_1, z_2, \dots, z_J)^T$ ,  $z_{\ell} = (z_1, z_2, \dots, z_n)^T$  can be obtained:



$$z_1 = b_1 \tag{3.26a}$$

$$z_{K} = b_{K} - \beta_{K} z_{K-1}$$
  $K = 2, 3, ..., J$  (3.26b)

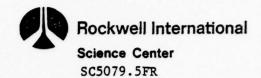
and (3.25) will give the solution vector x

$$\alpha_{J}x_{J} = z_{J} \tag{3.27a}$$

$$\alpha_{\ell-1} x_{\ell-1} = z_{\ell-1} - c_{\ell-1} x_{\ell} \qquad \ell = J, J-1, \dots, 2$$
 (3.27b)

## 3.4 Starting Procedure

The starting procedure is to employ a suitable discretization of the initial conditions obtained by the method described in Section 2.7. Glauert's similarity solution derived in Ref. 1 was implemented using the s = 0 specialization of Eqs. (3.3) and (3.4) for the results given in this report. However, with the compatibility restrictions given in Section 2.7, more general initial conditions could be accommodated including those derived from experimental data.



#### 4.0 PARAMETRIC STUDIES

In this section, results will be indicated typifying calculations using the computational model. Because of its interest on the XFV-12A augmenter, a logarithmic wing spiral contour, shown schematically in Fig. 3, will be discussed. In contrast to previously published solutions exemplified by Ref. 3, this discussion will deal with non-similar flows due to the nature of the assumed turbulence model. In Ref. 3, the logarithmic spiral shape with certain assumptions on the scaling of jet thickness with downstream distance gave rise to similitude and an analytic solution for the flow. The non-similar framework considered here makes such a solution unlikely and numerical methods must be used. In the notation of the figure, the equation of the spiral contour is

$$s = s_0 e^{\theta/K} , \qquad (4.1)$$

where s is the running arc length,  $\theta$  is the local inclination of the surface, where K and s<sub>0</sub> are constants. For K > 0, a convex contour is obtained, and with K < 0, concavity is implied. Equation (4.1) can be represented parametrically as

$$\frac{x}{R_0} = \left\{ e^{\theta/K} \left[ \sin\theta + K^{-1} \cos\theta \right] - K^{-1} \right\} / (1+K^{-2}) , \qquad (4.1a)$$

$$\frac{Y}{R_0} = \left\{ e^{\theta/K} \left[ K^{-1} \sin\theta - \cos\theta \right] + 1 \right\} / (1 + K^{-2}) , \qquad (4.2b)$$

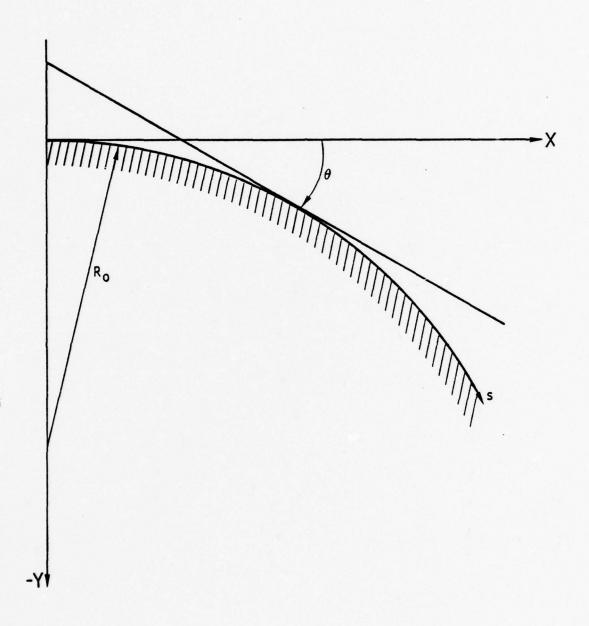
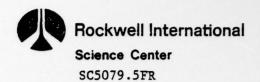


Fig. 3 Log spiral schematic



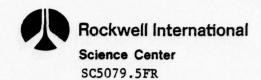
where  $R_0$  is the initial radius of curvature and X and Y are Cartesian coordinates shown in Fig. 3. Wall shapes associated with K = 0.05 and K = 1/3 are depicted in Fig. 4.

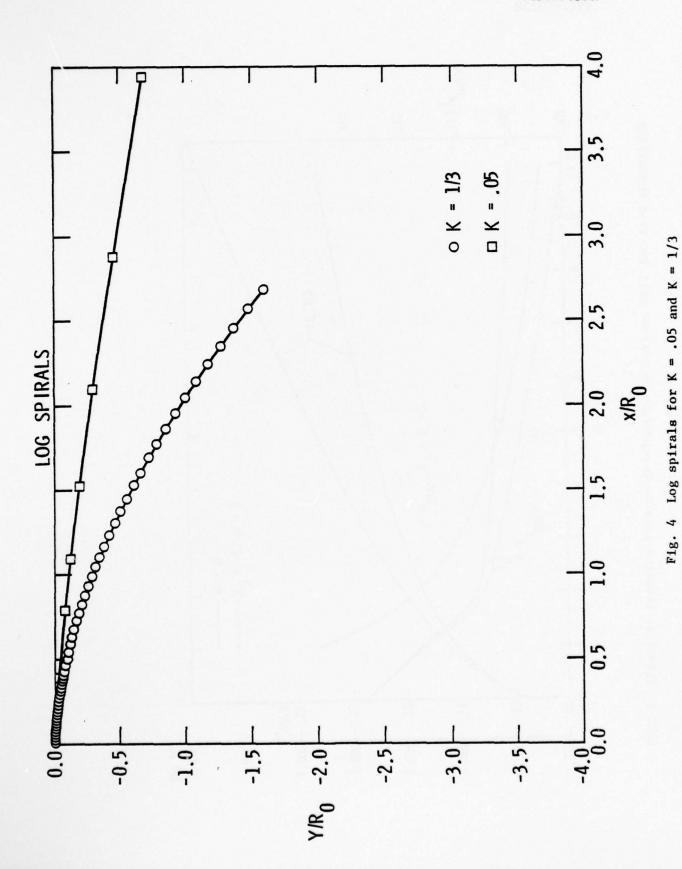
In Fig. 5, the peak normalized streamwise velocity  $f_{\max}$  with the max presence and absence of spanwise flow for a submerged wall jet  $(f_{\eta}(s,\infty)=0)$  is shown for K=1/3. For computational convenience, the cross flow was generated by the forcing term  $K_2u^2$  in (2.5d) with  $w(0,\infty)$  assumed zero. This effect can be thought of as the influence of spanwise curvature on the w field and its interaction with the mainstream flow. It is rather obvious that for  $K_2=-5$  a small degradation occurs due to the turbulent coupling which is virtually imperceptible when the physical variable  $u_{\max}$  is displayed. Another comparison shown for the effective mass entrainment function f(s,10) at the computational edge of the layer shows increased entrainment due to the cross flow.

Figure 6 indicates comparable small cross flow effects on the surface pressure distribution where the  $K_2 = -5$  case is compared to w = 0 for the K = 1/3 log spiral. The lack of  $s^{-1}$  scaling is due to the non-similar nature of the assumed turbulence model.

In Figs. 7 and 8, the streamwise development of the u and w profiles is shown. Although both profiles resemble each other, the momentum in the cross flow increases, in contrast to the decay exhibited by u. This trend is also indicated in Fig. 9 for w<sub>MAX</sub> and is due to the source-like manner in which the sidewash is produced.

To further assess the influence of turbulent coupling of the sidewash field on the mainstream flow, the effect of w on typical velocity profile is





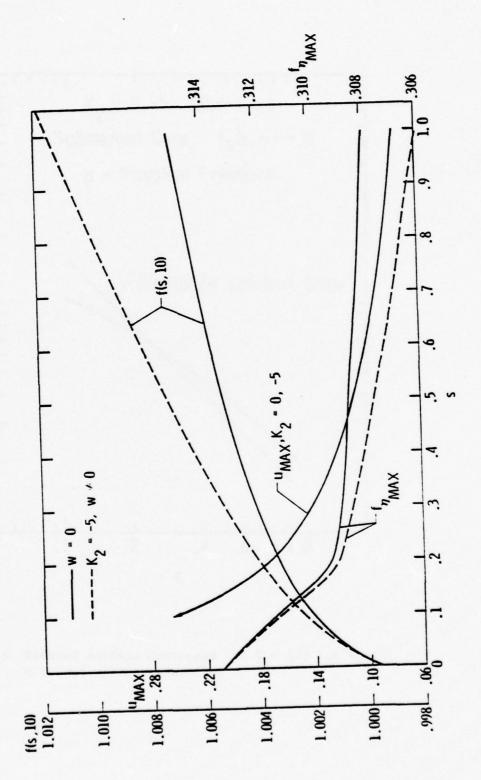


Fig. 5 Effect of spanwise flow on development of various wall jet flow quantities

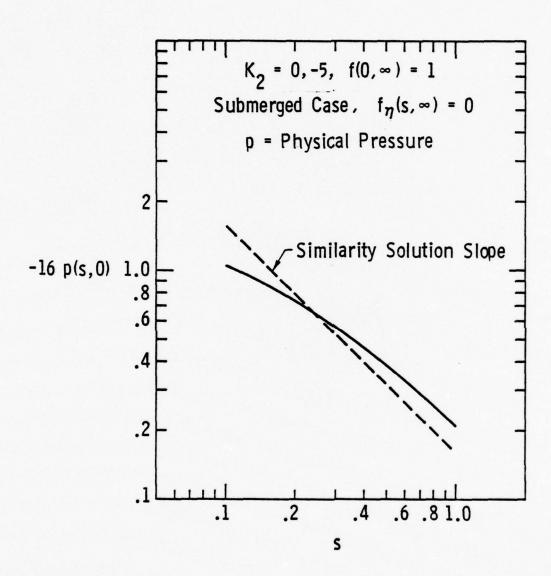


Fig. 6 Reduced surface pressures for K = 1/3 log spiral with and without span flow

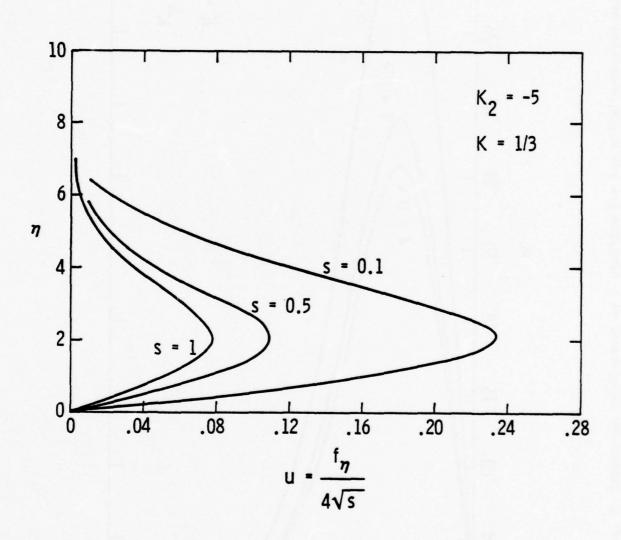
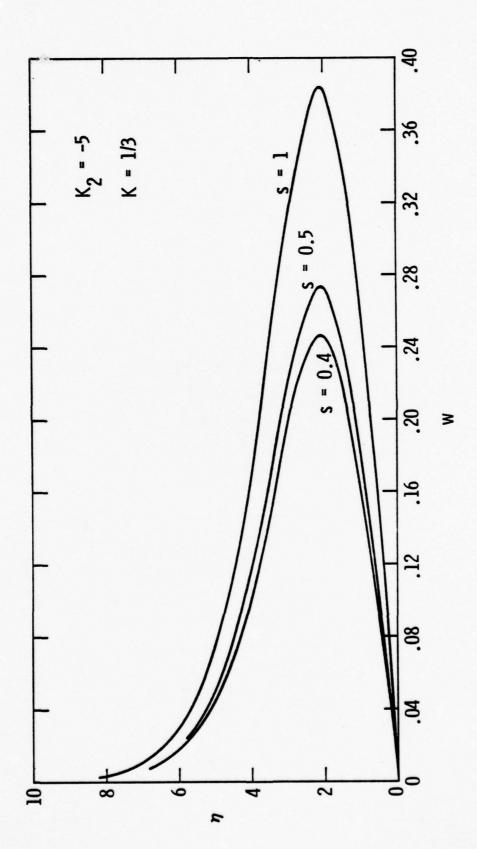


Fig. 7 Streamwise development of u profiles for log spiral-submerged wall jet with span flow



Streamwise development of w profiles for log spiral-submerged wall jet F18. 8



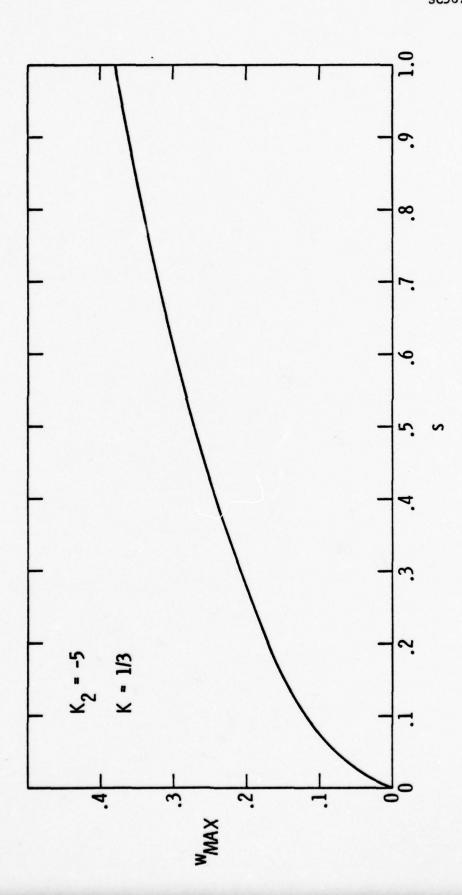
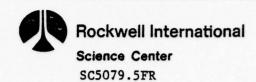


Fig. 9 Streamwise development of w<sub>MAX</sub> for log spiral submerged wall jet



shown in Fig. 10, where the peak region is magnified to show the very small effect of the crossflow.

To illustrate the resemblence of velocity profile of coflowing wall jets and conventional boundary layers, a point made in Section 2.5, calculations were performed using the typical model of Eqs. (2.5) with  $p = w = K_2 = f(0,0) = f_{\eta}(0,0) = 0, \text{ and } u(x,\infty) = 1. \text{ Results for the stream-wise development of the reduced velocity profile and shear stress on a flat plate with <math>f(0,\infty) = 4$  are shown in Figs. 11 and 12. To indicate the potentialities of the existing code, the streamwise velocity profile development with downstream distance is shown in Fig. 13 for a logarithmic spiral contour with cross flow. Here,  $K_2 = -10$ ,  $u(x,\infty) = f(0,\infty) = 1$ , and the external pressure gradient was neglected in the calculations. With this assumption, the qualitative downstream behavior resembles that of a flat plate.

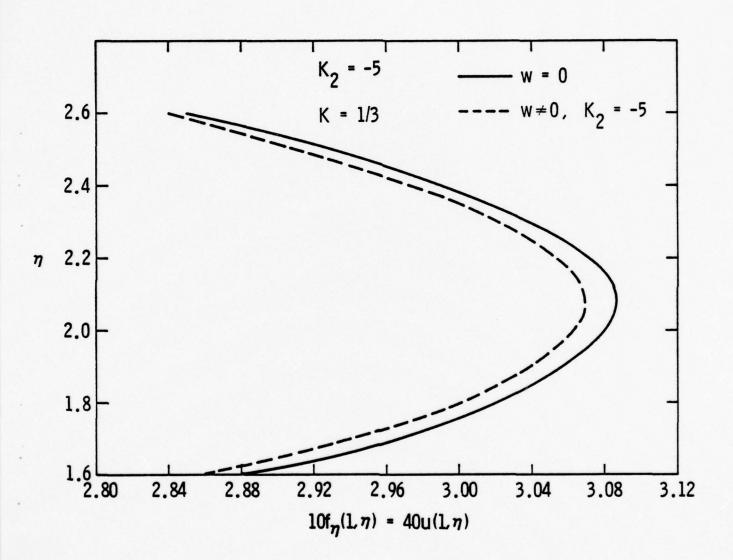


Fig. 10 Effect of spanwise flow on normalized u profile

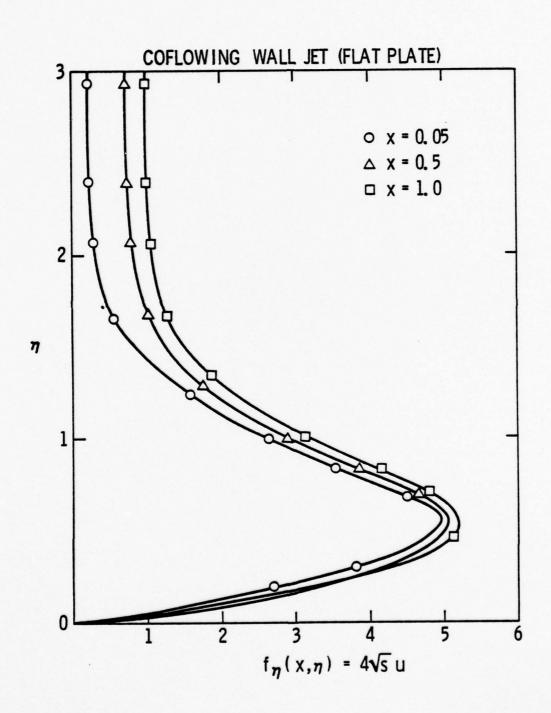


Fig. 11 Streamwise development of reduced velocity profile;  $p = w = K_2 = f(0,0) = f_n(0,0) = 0$ ,  $f(0,\infty) = 4$ 

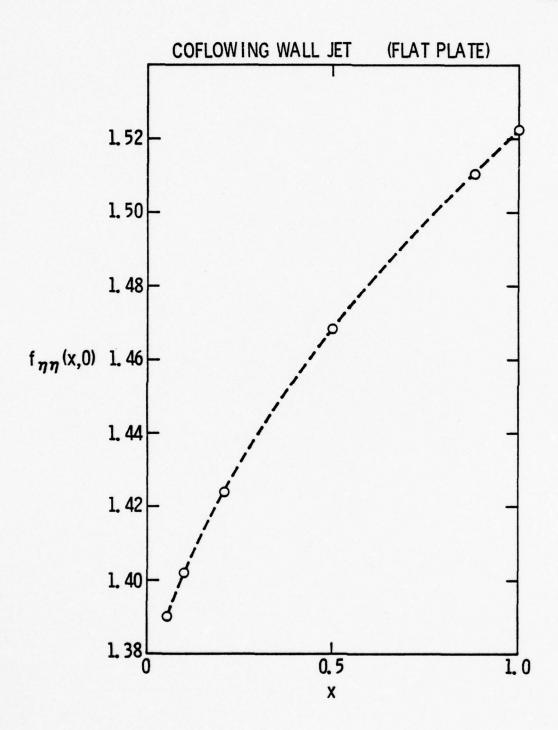
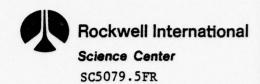


Fig. 12 Streamwise development of reduced wall shear stress;  $p = w = K_2 = f(0,0) = f_{\eta}(0,0) = 0$ ,  $f(0,\infty) = 4$ 



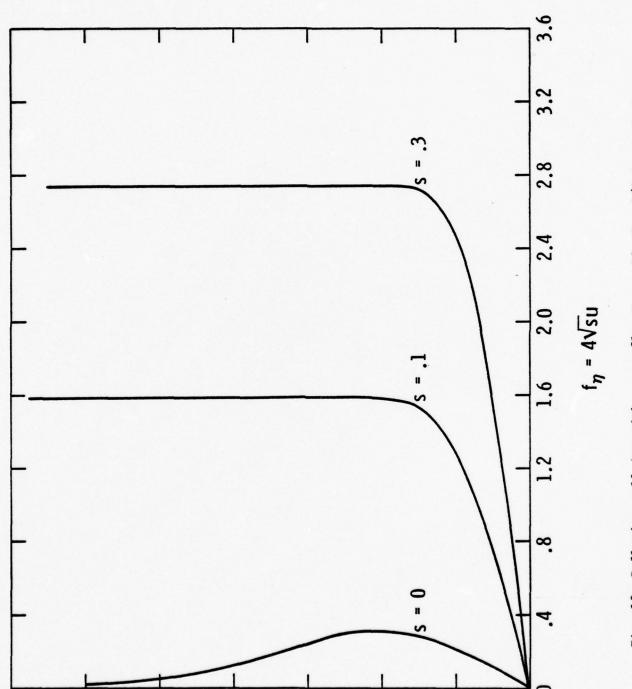
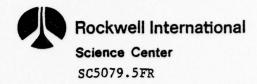


Fig. 13 Coflowing wall jet with cross flow  $K_2 = -10$ , K = 1/3 log spiral,  $u(x,\infty) = f(0,\infty) = 1$ 

4



#### 3.0 CONCLUSIONS AND RECOMMENDATIONS

A computational model using Keller's box scheme has been developed to treat incompressible turbulent wall jets in a small cross flow approximation. The computer code can handle sidewash w injected as a source term in the spanwise momentum equation. The effect of the span flow on the streamwise flow is due to the eddy viscosity coupling between the u and w fields. For this type of spanwise flow generation, the coupling appears extremely weak, reducing the peak streamwise component and causing growth of w momentum in the downstream direction.

In subsequent effort, different modes of sidewash addition will be investigated, i.e., through the boundary and initial conditions. The results of this are indicative of flow conditions for wall jets on configurations with slight taper or sweep. For handling more realistic situations, the foregoing analysis will be extended to finite cross flow.

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APPENDIX A: CODE LISTING AND SAMPLE INPUT AND OUTPUT

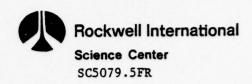


### Sample Computer Output

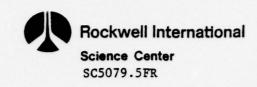
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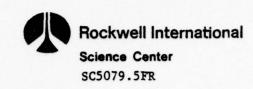
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THE PROPERTY OF THE PROPERTY O	ME MARCHED. THIS MUST BE SUPPLIED IN SUBROUTINE AMESH IF	ASUPLY=. IRUF.	INTEGER CONSTANT VARIABLE, NUMBER OF UNIFORM STREAMMISE	STATTOMS AT WHICH SULUTION IS TO BE PRIMIED (AH-KA) / NEW TIMI.	** INPUT: DEFAULT VALUE=10**	LUGICAL VARIABLE. =. IRUE. IF USER IS TO SUPPLY SIRLAMMISE	STATIONS IS AE PRINTED ON PAPER, **INPUT, DEFAULT VALUE=	*FALSE **	HEAL CONSIANT VARIABLE, (SZHZ) * DZUS (HZ)	CONSTANT	CONSTANT VARIABLE	CONSTANT NAMED OF STREET	CONSTANT	NSIANI VARIANLE, (S-0.5 FIX) / FIX	. VAKTABLE. =. INUF. IF VEKTICAL MESH IS TO BE REFINED	**IMPUI. DEFAULT VALUE = . IRUF **	HEAL VECTOR VARIABLE. USED IN SETUP OF BLOCK TRIDIAGONAL	SYSIEM	HEAL VECTUR VARIABLE. USED IN SETUP OF HLUCK IMIDIAGONAL	SYSIEM	HEAL VECTUR VARIABLE, STEAMWISE VELUCITY COMPUNEM AT THE	PRESENT STREAMWISE STATION, UT (N.L.) HAS THE VALUE OF ATH	CUMPONENT OF UT AT ETA = LIA(L) , WHEKE ETA(1) = YA=U AND	T (A (M) = F (A (M-1) + H (M-1) + HH) + HH) (M (M) HAS	VALUE (1) F. A.I. F. F.A.(3)	HERE VECTOR VARIABLE. STREAMAINE VELICITY COMPONENT AT THE	DELICATION CLATION	45.00			STUHASE CUNVENTION	REAL VECTOR VARIABLE, SPANNISE VELUCITY VECTOR AT THE	OUS SIRE	REAL CONSTANT VARIABLE, UMIFURA INTERVAL 10 WILCH SULUTION	IS IN HE PRINIED = (AN-AA) /IIPRINI	LUGICAL VARIABLE INUE. IF USER SUPPLIES THE STREAMISE	MESH . * HINPUL , DEFAUL I VALUE = . FALSI . * *	LUIGGAL VARIABLE. = - INUE. IF USER SUPPLIES THE VERITCAL		REAL CONSTANT VARIABLE. STARTING STREAMWISE STATEOUS =0	Ü	MESSI. (1.E. HIE LAS! SIMEARGISE STATION). **INPUL: DEFAUL!		REAL COUSTANT VARIABLE, THE LEFT END-POINT OF VERLICAL			MESH, ** INPUT OFFAUL OVALUE = 20. **			在		INPUT INTRACTIONS
National Section of Control of Co			NPIKINI			1110			ぇ	7.4	47		2 :	5	MET INE		H		Urix		ī					YIII		-	:		,	< - *		74		ASUPLY		ISUPLY		YY	Att			74		TH.				***	•	Highil #
j															2.4						11											,	23				23	0	0	2	0		23	1	4	12	C	:)	1)	-		



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00001650 00001550 00001560 00001580 00001280 00001620 00001000 00001640 00001660 02910000 00001680 00001520 00001530 00001540 00001570 0001000 00001610 06910000 0001000 FUN COFLOWING CASES. USER MUSI INDUI ARBITRARY FUNCTION (SEE DESCRIP-110N OF INTEGER VARIABLE C4) IN THE SUBROUTINE NAMED BC IF THE LUGICAL VARIABLE YSUPLY=. IRUE. . USER MUST INPUT VERTICAL MESH YNE SH MESH AND TOTAL NUMBER OF STREAMWISE STATIONS THROUGH THE SUBMOUTINE IF THE LOGICAL VARIABLE XSUPLY=. IPUE., USEK MUST INPUT STREAMWISE ASUPLY+YSUPLY+AH+MKS+FACX+J+REFINE+MMA+OPIPT+MPRINI+C3+KL AND TOTAL NUMBER OF VERLICAL POINTS THROUGH SUBROUTINE NAMED FUR INPUT: THE FULLOWING VARIABLES MUST BE SUPPLIFU BY USER WITH 1HE FULLOWING UPITUNAL C1.C4.C7.CASEW NAME D AME SH

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OSCILLATIONS ARE DEFECTED IN THE SOLUTION BETWEEN SUCCESSIVE INDUMLE SMOOTING AND SOME HINIS IN USING IMIS PROGRAM C

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THE SOLUTION AT ETA=YB DOLS NOT GUTET DOWN SUFFICIENTLY, 18 SHOULD POINTS IN LITHER STREAMWISE ON VEHIICAL DIRECTIONS, MESH SHOULD BE HALVED IN THAT DIMECTION AND CALCULATIONS SHOULD BE DONE ACAIN TO CHECK IF THE USCILLATION IS TRULY A PHYSICAL PHENUMENON, HATHER IMAN NUMERICAL STAHILITY. MESHES SHOULD AL SO CHOSEN TO ENSURE SULUTIONS AGREF TO NUMFRICAL ACCURACY WHEN MESHES ARE HALVED INCREASED C

ACHIEVE STATCLER CONVERGENCE IN MEWTON S ITERATION, EPSEAR SHOULD DECKEASED (RUST BE GREATER THAN 1.1-1.3 WITH CDC 6600) ARD MAXITS INCKEASED. THESE CAN HE DONE BY CHANGLING THE DATA STATEMENT IN MAIN PROGRAM

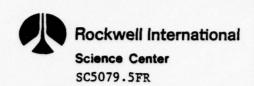
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00001860 01810000 00001880 00001890 00010000 01610000

> IF MUNE POINTS ARE DESTRED, JUAN SHOULD DE LUCHEASED HY CHANGING DATA HE USED TO BET HIGHER ORDER SOLUTION IN BOTH STREAMWISE AND VERTICAL IF MORE ACCURATE SOLUTION IS DESTRED, ALCHARDSON EXTRAPOLATION CAN LINE CITONS

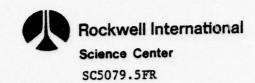
STATEMENT IN MAIN PROBRAM. THE COMMON STATEMIND IN THE MAIN PROGRAM. LAKEN IN THE COMPUNENT CONVENTION THAT "AS EXPERIMED IN VARIABLE IF USER WISHES TO SUPPLY OUNTILITAL PROFILE, SUCH A PROFILE HUS SATISTY WALL-IET ASSUMPTIONS. THE PROGRAM HAS TO BE MODIFIED BY CHANGING STATEMENTS IN THE SUPROUTINE NAMED PREP, CARE MUST BE HAVE IN HE CHANGED ACCORDINGLY.

FOR LARGE INTITAL MASS FLUX (C.) GREATER THAN UNE), IT IS RECOMMENDED THAT THE MUTTOR OF CONTINUALIUM (FC) SHOULD ALSO BE HIGHER. A USEFUL DESCRIPTION OF UI

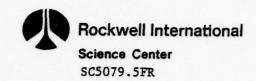


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	C HETTINGE I 1.16. KELLER - A NEW UITTENEE SCHEME FOR PARABOLIC		C SOLUTIONS OF PARITAL DIFFERENTIAL	C EUUATIUMS 11, PP. 327-350, 1971.	MEFFIRENCE & GLAUERI -	C MECHANICS VOLUME 1 PP-625-0431 1956	3	3		_	/WKTE		-	COMMON INET JNAXOHMAXOIPNXONSANE	14 HKA (15)	CUMMON /UI/ UI(4+151) /UIX/ UTX(4+151) /UU/ UU(4+151)		4(4,4,151) /b/ b(2,4,151) /c/ C		CUMMON /SETUP/ UH(4) + UHX (+) +FF (4) + AJA (4+4)	CUMMON /NPHI/ KPHI(151)	CUMMON /HINEW/ HNEW (151)	-			/FAM4/	/PARMS/	COMMON ARPIA RPI (56)		HAMELISI /INPUIS/ CASEMOASUPLYOYSHPLYOXBOYAOHKSOFACAO JOHEFINEO	1 HMAX, (HTPT), NPHINI, CI, CC, (3, C4, C5, Cb, C1, KC	DATA MAKITS OF PSEKKOKELOCUTOFF ON TESTONO NW /15010F-600 PALSE.	F-39504	UAIN AMA IISI	C DEFAULT AND INFO		UpipT=.talgt.	CASEUs. INU!	CASEM=. INIF.	ASUPL.Y=++ nl. 51 .	15UPLY=+FALSE.	KF INE = 1 FUF.	NPKINI=10	FACX=1.6	HNS=1-1-2	Υισεύ•	

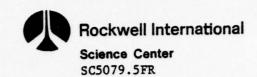
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	(\d\ \.)\(\(\d\ \\)\\\\\\\\\\\\\\\\\\\\\\\\\\\\		IN I			-			NC=1	C INITIALISE		-			N I E to 2 I	C VECTUR ** 6 ** IS SET TO ONE FUR THE LAMINAR CASE				10 K=1.2	(,t_)=1.		UU < 0 K=1,4	0)x(k,L)=u.		CONTINUE		MALIF (1 LADIII.)			tw)	SUPPROUTING WALDET (KSTAPT)	COMMITTEE THE STOP AMMILE DEVELOUMENT OF FIRME OF BOTH	OF THE STREAMWISE VELUCITY AND SPANWISE VELUCITY FUR A IMPEG.	DIMENSIONAL MALL-JET ON A CURVED SUPPACE WITH SMALL CRUSS-FLOW	C ASSUMPTION			/SOLVEY CASFU-CASE	(MESHA/ HKA(1) /MEShY/ H(1) /UI/ UI(4+1) /UIA/ UIA(4+1)	767 (5(441) /WI/ WI(241) /WIX/ WIX(241)	/rakm2/ /1.02./3./4.75./6	COMPLUS ANARMA MAAILSOENSERNORIENOALIONESI COMMUNICATION ANARA INTERNATIONALIONESI COMMUNICATIONALIONALIONALIONALIONALIONALIONALIONAL	

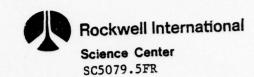


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																									HEU IN VECTOR ** X	PREVIOUS STREAMWISE										PRESENT STATION											
	NN. XN. HX. X												L pRUFILE							NA III			XH-WX		LALION IS	VALUE AT										MUMENTUM EQUALTON AT ITE PRE		EU.NU.NL.NU)		.OR. (NIEK-Eu-0)) to 10 1159						MOMENTUM EGUALION SULULION	
			N=4	NPEC	Ne s	NPW.1	NG#11	KASEU=2	NASEW=3	NANP=1			I UP MESHES AND INITIAL		KI-K-14H 1.1	1+142.542.4	VO 2000 AGINIERIAN	KOIN	HATHER (KILINI)	( 14 )		メニメルーバネ/ / -	#H11F (Depugn) Killin - XN-HX		PKEVIUM	AS A FIRST GUESS TO EDDY	SIALLUN 15 USED		1140		0 (114(N+L)=U1(K+L)			-		CUMPULE STREAMINTSE MUMEN		CALL NEW JUN (KASEUINU		IF ( C. NOI - CASEW) - OR. [		C4   1   1   1   1   1   1   1   1   1	MIN OCITION	MINING THE TENT (K.L.)		CUMPULE SPANIATSE NOMENTUR	
Principal Princi		J									ပ		ر ک <del>د</del> ا	,		J									70 0.0 5.0		c Sı	٥			200			1143	၁		၁	,	٥	,	٥				0011		

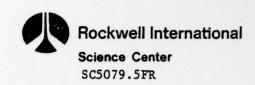


	00003530	
1159 CAMITMUE	00003540	
EXII IF NO COMVERGENCE	00003550	
1r (N.F to to 2100	00003570	
	00003290	
IF (*NOI-UPIPI) AU TO 1250 IF (*NOI-UPIPI) ANU. (XN-GE-KANP#XPKI)) GO IO 1200	00003610	
ND. (KOUNT.EQ.KPHI (KKNP))) 60 10 1	00003620	
60 TO 1300	00003630	
KANPIE ANDE	00003650	
CUNTINUE	00003660	
	00003670	
C WRITE SOUDION DAPER	00003680	
CALL OUIPT(JoYA)	00003700	
CONTINUE	00003710	
	00003720	
1F (U) (3,1), GE,0,) 60 10 2050	00003740	
	00003750	
SEPARATION, INTRO DEMINATIVE OF F (STREAM-FUNCTION OF STREAMUSE VELOCITY) IS NEGATIVE	00003700	
	08720000	
*** [f. (6,6200)	06150000	
CALL UUIFI(J, IA)	00003800	
CONTINUE	00003810	
1F (XN. 6E. AH) 60 10 2100	00003830	
CONTINUE	00003840	
CONITABLE	00003850	
FULMATER : AATION = # - [4.4] × - 4 - 4 - 4 - 4 - 4 - 4 - 4 - 4 - 4 -	00003860	
O(HZ) SOLUTION#)	00003880	
FUHMATICZZ XXXXXXXXXXXXX SEPARATION XXXXXXXXXXXXXXXXX	06860000	
	00003900	
AF LOXA	00000000	
SUBHOUTINE PREP (NSTART)	00003930	
	00003940	
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LUGICAL ASUPLY, YSUPLY, REFINE, OPIPI	06650000	
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00004120 00004140 00004160 00004210 00004220 00004540 00004250 00004260 00004210 00004280 00004590 00004300 00004310 00004320 00004330 00004340 00004350 00004360 00004370 08640000 06649000 00044000 00004410 00004450 0544000 0000000 00004450 00004400 00004470 00004480 06440000 005\*0000 00004510 10004530 00004040 00004050 0000000 0/04000 06040000 06040000 0004100 00004110 00004130 00004150 010000 00004180 06140000 0024000 00004530 00004520 COMMON /UT/ UI(4+1) /UU/ UU(4+1) /F/ F(4+1) /UTX/ UIX(4+1) MAXI IS. EPSERHON IENO YELOCULUFFOMIESI Ir ((XI-NI\*XPI).61. (HKX (KL)/20.)) 60 10 120 IF ((KL-61-100).0K-(XI-6T-XH)) 60 [0 1+0 CUMMUN / PARMS/ FACX, HKS, KA, KU, YA, Y J, NA HINA (KL+1) =HKA (KL) \*FACX+ (AI-KI \* KPI) CUMMON INFIL JMAX . HMAX . IF MX . KSAME F3(1)=-2. \*E KP (-1)/(1. +EXP (-1)) \*\*2 CUMMUN / PARME/ PIOP20 P30 P40 P50 Pto F4(1)=<+\*+ xP(-1)/()+++xP(-1)) \*\* F ((1)=(1.-ExP(-1))/(1.+ExP(-1)) CUMMUN / LAIRMS KUUN] , XN . 11 X . IF (XI. 6E. (KI \* XPI)) 60 TO 110 HKX (KL) = N [ \* / P | - ( X | - MKX (KL) ) 1KK (NI,) = E. I BAP (- (X I - HKX (KL)) HKX (KL) = N ( \* XP I - ( X I - HKX (KL) ) IF (MKX (NL) . 6] . XPT) FACX=1. 11 (FACX-EU.1.) 60 TO 130 06 01 . . . . . HAX (KL+1) =HAX (KL) \*FACX HKA (KL+C) = HKA (KL) \*FACX D.MN.DN HNA (KL + 1) = x | -K | + XP IF ( NO I SASIILY) 60 /hunrd/ /FWHWA/ ( I = Y I + HKX (KL) C SIREAMWISE MESH CALL AMESI HKX (I) =HKS 00 IO 150 001 01 09 001 01 00 001 01 00 AI=KI#API CON I INUE CON! INUE · 0=(1)+4 CONTINUE CONTINUE CONTINUE KL=NL+Z KI=NI+1 A [ =-IIKS KL=NL+1 KL=nL+1 K-1 = K 1 + 1 COMMON COMMON KL=1 11 2 001 120 130 90

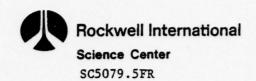


00004750 00004770 00640000 09940000 01940000 0004000 00004780 06240000 00004810 00004820 00004840 00004850 00004860 00004870 00004880 00004870 016+0000 00004930 00000000 09640000 00005010 00000000 00002040 00004260 00004570 08540000 00004590 00940000 00004610 00004620 00004630 00000000 00004650 00004680 06940000 00004110 00004720 00004730 00004740 00044000 00840000 00004830 00004650 00004950 01640000 08640000 06640000 00050000 0000000 SULVES FUR INITIAL SIMILAR SULUTION 1F (.NO] . YSUPLY) 60 TO 350 IF (A1-LE-AH) 60 TO 135 IF (KSTAKI.61.1) RETURN IF (Upipi) CALL PRMESH JA=(J-1) # 3./5. 10 170 L=JH9J1 NO 164 L=1,JA #1=24 YH/3./JC UN 190 K=1.NU INX (KE + 1) = XPI U1 (1.1)=+1 (Y) U1 (2.1) =1 2(Y) U1 (3.1.) = 1 1(Y) A I = A I + HINA (KL) UI (4,L)=++(Y) UU 190 L=113 C. 1=1 000 00 UIX (K+L.) = 11. MI=YH/3./.JA CALL YMESH 00 10 400 C VERTICAL MESH JC=J-1-JA CONTINCE CON INDE CUNI I NUE 150 CONTINUE CONTINUE CUNIINUE CONTINUE (=X+H(1) CUNITNUE Jh=JA+1 H(L)=H] H(L)=H] H(7)=0. 11=11 NAFKL-I NL=KL+1 1-0-10 1-0-10 1=0 135 150 170 400 140 100 190 00 C C C U C

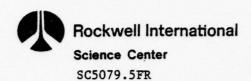


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76±7 76±7	C DUMMI INITIALISATION	HA=1,	I I NOON	SHON	ν=0• C	C35AVE=C3	C3=U. UC3=C35AVE/KC	C CONTINUATION SHOCEDURE TO OBTAIN INTITAL PROFILE FOR MASS FLUX = C3		10 2400 KCONJ=1.KC	CALL NE. (ON (2, N+NP, ND)	1F (-NO)-HFFINE, 60 TO 2100	LALL NEIKUN	10.2.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1		IF (RSAME - F.S 1) CALL NEWTON (Z. N. N. N. N. )			#KILL SOLUTION ON PAPER FOR THIS MASS FOR - CON WHERE # KCONI * UCS	7 1 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	Ar of the tue of Slor	11 (KCON1.EO.KC) 50 TO 2500	C OBTAIN IMPRODUED INTITIAL GIFES FOR NEXT CA BY SOLVING FIRST	VARIATIONAL EQUATION	C		ON-120 00 2200 00 2200 00 2200 00 2200 00 2200 00	F (3+2) =1.+2.8 (U1 (2.5.4) +UT (3.4) /C3) /C3**2	CALL MLUCKZ	00 2340 L=1•J	ONI TEN DIES ON	CONTINUE	

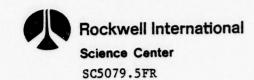
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CHANGE IN CHANGE IN DEP [NEW, NI 9]	00005570	
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PERSONAL INC. IN. IN. ION (KASE, NI. NZ. N. J.)	00005610	
	00005620	
THE STATE MONENTUM SULVES FOR THE STREAMUISE MONENTUM EQUALTON OF NEWTON		
EMALION.	00005640	
10.	00002650	
LINEAR A CONSECUENCE OF SMALL CROSS-FLOW ASSUMPTION.	00005660	
	00005670	
L MEL	00005680	
/PAHMI/	00002690	
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LAKM3/	01/50000	
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EATERNAL JACOB HISE BC. RHOFW HCW JACOB	00005760	
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C INITIALISE	00005780	
	000000	
ININ	0005800	
NP=N2	00005810	
S N = M =	00005820	
70= (XN54HX)/HX	00005830	
IF (ROUNI .F.Q. 1) P6=0.	00005840	
IFLAU=1	00005850	
11C=0.	00005860	
Y10LU=0.	00005870	
	00005880	
	00005890	
C ENUALION	00650000	
It (Machata) Call partie	02650000	
( · · · · · · · · · · · · · · · · · ·	00005930	
C CONTRIBUTION FROM PREVIOUS STALLON FOR THE SPANNISE MOMENTUM EQUATION		
IF (KASE. E. 1.3) CALL PARPOW	00002960	
	07650000	
C NEWTON I TERATION	08650000	
DO 300 M=1-MAXII>	0000000	
	00000000	
	0000000	
C SULVE FUR STATAMISE MOMENTUM EQUALITION	00000000	
. ·	0000000	
Ir (AASE "E 1, 2) CALL BOX (KASE + KHSF + JAC 10+BC)	0000000	
	0000000	



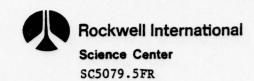
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	IF (NASE .E 3) CALL BOX (KASE . LITER . JACODE . BCW)		C CALL BLOCK INIDIAGONAL MATRIX SOLVER		CALL BLUCK)	CALL BLUCK	Ir (MASE . E.) 60 10 190		C SHANWISE SULUITON				IND WI (NoL) = DU(KoL)	AF LUKN	TANK INC. OF	ל את במיל נותור	C ELLO TESTING BETWEEEN IND NEWTON ITELATES		EHMAX=0.	UU 200 L±1,J	UU 200 K=1,™	UI (K+L) = UI (K+L) + IIU (N+L)				C .PALSE.	JE C. NOT. 05 10 105.	- 5				LUCY=L	LHM4X=EHHUH	200 CONTINUE		22	MHILE (6,6000) M, EMMAX, LOCA, LUCY, YICC, UI (3,1), UI (4,1)	HE TURN		50 10 210		210 CUMITINUE	EKULU=EKMAX			360 CONTINUE	



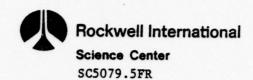
00000590 00000500 00000510 00006520	00006650 00006652 00006652 00006660 0000660 00006690 00006700 00006710	00006740 00006740 00006760 00006780 00006780 00006810 00006820 00006820 00006830	000006870 000006880 000006890 000006910 000006930 000006940 000006940 000006940 000007010 00007010 00007010
C NO CONVERGENCE. WRITE FINAL LIERATE AND LAIT.  C KIEH=0 AMITE(0:6100) CALL UDIPI(J.YA)	C 6000 FURMATI(* NEWJON - IJER =**!Z** EHRUH =**E12.5** AT(**12****13**  1	COMMON /WE/MEY ASE = 3  EQUATION WHEN KASE = 3  COMMON /WE/MEY H(1) /U/ U(4.1) /U// UIA/ UIA/(4.1) /G/ COMMON /WE/MEY H(1) /U// U(4.1) /U// UIA/ UIA/(4.1) /G/ COMMON /WE/WE/ WE(2.1) /WEX/ WE/(2.1)  COMMON /WE/WE/ UI(4).UHXN(4).FF(4).AJA(4.4)  COMMON /PARME/ N.NP.NN  COMMON /PARME/ P1.P2.P3.P4.P5.P0  COMMON /PARME/ NU.NW.J  COMMON /PARME/ FACX.HKS.KA.KH.YA.Y1.NA  COMMON /PARME/ KUUNI.XN.HA.X	J1=J-1  J0 30 M=1, J  J0 30 L=1, N  D0 10 K=1, NP  A(K,L,M) = 0.  L0 d(K,L,M) = 0.  C(K,L,M) = 0



060/0000	001,000	011/0000	000001150	00007130	000001140	00007150	0000 1160	00000110	000001180	0011000	0000 7200	00000/210	000001550	000001530	00001240	0000 7550	00001200	000001210	00001280	062/0000	0000 1300	0000 /310	0000/320	00000	0000/340	0000 7350	0001000	01610000	06277700	00001400	000007410	00001420	00007430	0000 7440	0000 7450	000000000000000000000000000000000000000	08470000	064/0000	00001500	0000 7510	00007520	0000 7530	00001540	00001220	095/0000		
																																															M) +(1(3+M)-(1(3+M)-(1(3+M)+0(2+M)) *(U(3+M))+P3*U(2+M))
																			(K.M))/2.	•								H(M1) *FF(K)								H (M) 1 644 (h J)				IMEANAISE STALLOW			• M1)	11,00	· 141)	( W •	[M42)0+ (M48) 8-11H4
 Ź.	1)=AJA(N.L.)	=-FF (K)	200 K=1.N3	L=1,N	.L.J. = AJA (K+NP.L)	. J) = - FF (K+NP)		210 L=1,N	N. 1=X	L, = .1 .		POINTS CONTHIBUTION			M=2.0		HEPP(Y)			(U(K.M1)+U(K,M))/2.	ACUIS		K=1,N0		L=1.N	A (K.L) *H(M1) /2.	A (K - L - M ) - LA	MI) = H(K - M) - H(K - M) + H(M) ) + FF(K)		MI)=1.+(K, K, MI)		2	00 /00 L=1.N	111=-AJA (K4.L) "H(M1) /2.	M) =HA	E (N. 1, -14) = HA	TO CHANGE TO CHANGE			ON FROM PREVIOUS STREAMISE		,t.t. 1.3) GU TO 450	M)=4(1,2,M)_P346(2,M1)	(4)=1(1,3,4)+10-(6(2,141)	(M+2) 9464 (M+2+1) == (M	M)=1(1,3,M)-1.+6(2,M)	=+ (1-M)+11(3+M)-11(3
	מם שועירייון=	_	002 00	001 00	ī	200 F (N+NP.J)=-	3	012 00	UU 210 K=1.	210 AJA(N.		INTERNAL		(1) / S X X X X X X X X X X X X X X X X X X	12-₩ 006 OU	MI=M-I	CALL PHEPP	008 00		300 UH(K)=(U(K.	CALL JACON	CALL KHSF	א טטס טט	AF=K+NF	JO 200 F	HA=-AJA (N.L		F (KP-M1) EUC	A (NP.	500 C(K+K+M1)=		MU-X-PX	007 00	VI		TOO BILLIAN THE	THE WASHINGTON	800 G(K•K3•M)		C CUNIMING TON		IF INASE .E	H(1 2.	0(1,3,	A(1,2,	A(1939	F(1.4)=+ (1.m

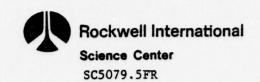


	00007590	00007610 00007620 00007640 00007650 00007660 00007680 00007700		0000/810 0000/820 0000/840 0000/850 0000/860 0000/860	00007900 00007910 00007920 00007930 00007940 00007960 00007960	00000000000000000000000000000000000000
			HLUCK			
	F (2+4) = F (2+M) = 5 (4+M)	CON! [NUE d(1,1,M)=H(1,1,M)-P3+L(2, d(1,2,M)=H(1,2,M)+1,-L(2, A(1,2,M)=A(1,2,M)-1,+G(2, F(2,M1)=0. F(2,M1)=0. F(1,M)=-L(3,M) CON! [NUE Y=Y+(H(M))+H(M))/2.	FO ENSURE THE FTRST OF THE BLOCK TRIDIAGONAL.  TO 960	L  = 1   K S W   C 4 = 1   N = 2   C ON   I N U E   U		

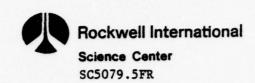


	00008110	00008130	00000150	00008170	00008180	00008190	00008210	00008220	00008250	000008560	00008270	00000000	000008310	00008320	00006330	00008340	00008360	00008370	00000000	00008400	0148000	00008430	00008440	00008420	00008460	0000000	00008490	00004510	0000000	00000830	00008550	00008560	07.580000	06960000	
Charles and Cacadhahan is 11		/PARM4/	00 100 L=1+J	Kil		CALL LUSULV(1)	3	N1=M-1	C AMEM	CALL BEIASV(KM)	C SULVE SCALAH MAIKIK ALPHA	C 500 K=1. Mo.	4.00	SUM=0.		200 307=30M=1: (K+AN+NP+M) *(: (KN+L+M)) A (K+L+M) = A (K+L+M) + SUM		SOU COMPLIANCE	CALL LUSOLV(KM)	· · ·	600 Canilhir		AE IURN		SUBREGULINE LUSOLV(KM)	C IMIS SUMMOUTINE DECOMPOSÉS A SECALAH MAINIX INTO LU-FORM USINO	C A MINEU PIVOLING SIRAIFOI						C SEARCH FOR UPITIMAL PIVOT	N. = 14 [	

0198010	0298000	05.0000	000008640	00008650	09980000	0.000000	00008680	06980090	00008100	000008710	00008720	00008730	0000000	05180000	000000	0000000	000000	0618000	000000	0188000	0288000	00008830	04880000	0.000000	0000000	0.880000	000008890	00680000	01680000	0000000	0E6R0000	0000000	0548000	09690000	010000	0869000	06680000	0.00000	0000000	0000000	04060000	05060000	04060000	01060000	08060000	06060000	00160000
HIGH MACHINES	INCHENC (MI + NM)	(EX. INC. INC. INC. INC. INC. INC. INC. INC	ROLLON = CPIVOI	DO 200 K=4.N	HINER (Norm)		Ir (anstretvol) . GE . ABS (A (WERS INCM . N. )) 66 10 100		NAHA	KPIVOI=A (NHK, NCM, KM)	100 CUNIINUE		NC=K	CPIVOT=A (NRM+NCK+KM)		IF ("BS (MPIVOI) . OE - ABS (CPIVOI)) GO TO 400		C PIVOL BY INITACHANGING COLUMN		IF (AMS (Cp   VOI) . LI . I . E - 10) WRITE (6, 5000) NM, MI . Cp I VOI				MC INC AND END OF THE ONE	(	C GAUSSIAN ELIMINATION		UU 300 L=4,N	HCL_NC (L, KM)	A (NHM, NCL, KM) = A (NHM, NCL, KM) / (HIV)	I = A (NRM, NCL, KM)	UU 300 N=M+N	HKK = FAIR (K + KM)	300 A (WHEN MCL . KM) = A (MHK . NCL . FI) - I # A (MKK . K I . KM)	60 10 600		C PIVOL BY IMPERCHANGING RUN	400 Cowiliane			It (AK. OL M.) ASION=KSIGN+1	GF (KROKM) ENK (MIONM)	14 (14 . n.M) = n 1		C 64USSIAM FLIMINALION	2	Dr. 508 Law,N



160000			The state of the s
**************************************		A (HHL 1, NCH, NR)   A (HHL 1, NCH, NR)   A (HHL 1, NCH, NR)     U C SOD (A (HR)   A (HHL 1, NCH, NR)     U C SOD (A (HR)   A (HHL 1, NCH, NR)     U C SOD (A (HR)   A (HHL 1, NCH, NR)     U C SOD (A (HR)   A (HR)   A (HR)   A (HR)     U C SOD (A (HR)   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)     U C C   A (HR)   A (HR)     U C C   A (HR)     U C C C C   A (HR)     U C C C C C C C C C C C C C C C C C C	1 = A (MKL, NCM, κM) = A (MKL, NK, NF) / NF   VU     1 = A (MKL, NCM, κM) = A (MKL, NK, NF) / NF   VU     1 = A (MKL, NCM, κM) = A (MKL, NK, NF) / NF     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM)     1 = A (MKL, NCK, MK)     1 = A (MK, MK, MK, MK, MK, MK, MK, MK, MK, MK,
Li = L(Li Li Li Li)   Li = L(Li Li Li)   Li = Li		Hett, Weik Ref = a (wit, Nic4, Ni	Latint, win, km, = a (wit, Mc, A, Rr), JrP 1 vol.     Latint, win, km, = a (wit, Mc, A, Rr), JrP 1 vol.     Latint, win, km, = a (wit, Mc, A, Rr), JrP 1 vol.     Latint, win, km, = a (wit, Mc, Rr) - latint, (a, blood)     Latint, win, km, = a (wit, Mc, Rr) - latint, (a, blood)     Latint, win, win, win, win, win, win, win, win
1 = 1 = 4 (1041, 104 (1.14))  1 = 1 = 4 (1041, 104 (1.14))  1 = 1 = 4 (1041, 104 (1.14))  1 = 1 = 4 (1041, 104 (1.14))  1 = 1 = 4 (1.14)  1 = 1 = 4 (1.14)  1 = 1 = 4 (1.14)  1 = 1 = 4 (1.14)  1 = 1 = 4 (1.14)  1		A (HHEL, NCH, NCH, NCH, NCH, NCH, NCH, NCH, NCH	
1 = 1 = 4 (1041, 104 CH ) + 1 = 4 (11, 105 CH ) + 1 = 4 (1041, 104 CH ) + 1 = 4 (1041, 104 CH ) + 1 = 4 (11, 105 CH ) + 1 = 4 (11,	= a(arti ************************************	A (HHEL, NO, HR)   A (HHEL, NO, HR)   A (HHEL, NO, HR)     O (0 500 A (HR)   A (HHEL)	
1 = 1 = 4 (1041 + 104 + 104)   1 = 4 (11 + 104 + 104)   1 = 4 (11 + 104 + 104)   1 = 4 (1041 + 104 + 104)   1 = 4 (11 + 104 + 104)   1 = 4 (11 + 104 + 104)   1 = 4 (11 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11 + 104 + 104 + 104)   1 = 4 (11		Hett, Wick, Ref = a (wit, N(A, NE), / NE)   Let (with with with ref)     U (C 500 Remin Ref) = a (wit, N(A, NE), / NE)   Let (with with ref)     U (C 500 Remin Ref) = a (wit, N(R*KM) -   Pa(K1, NE)     U (C 500 Remin Ref) = a (wit, NE)     U (C 500 Remin Ref) = a (wit, NE)     U (C 500 Remin Ref) = a (wit, NE)     I (AHS) (a (with)     I (With)     I (AHS) (a (with)     I (	
Li = L(Li Li Li Li)   Li = L(Li Li Li)   Li = Li		Hert   New   Ker   = A (MHL, NCA, NE) / NED   U (C 500 Remark RR) = A (MHL, NCA, NE)     U (C 500 Remark RR) = A (MHL, NCR, NE)   Pa (K1, NCA, NE)     U (C 500 Remark RR) = A (MHL, NCR, NE)   Pa (K1, NCA, NE)     U (C 500 Remark RR) = A (MHL, NCR, NE)     U (C 500 Remark RR) = A (MHL, NCR, NE)     U (C 500 Remark RR) = A (MHL, NCR, NE)     U (C 500 Remark RR) = A (MHL, NCR, NE)     U (C 500 Remark RR) = A (MHL, NCR, NE)     U (C 500 Remark RR)     U (C 600 Mel RR)     U (C	Latint, win, km, and
Li = L(Link, Link)   Link		HINEL   STATE   STA	1
Li = L(LHL, WCHN, KH)     UG 500 REH, WCHN, KH)     UG 500 REH, WCHN, KH)     UG 500 REH, WCH, WCH, WCH, WCH, WCH, WCH, WCH, WC		HITELLINE   HITELLINE     HITELLINE	1
1 = 1 = 4 (1041, 104 CH × 104)  1 = 1 = 4 (1041, 104 CH × 104)  1 = 4 (1041, 104 CH × 104)  1 = 4 (1041, 104 CH × 104)  1 = 4 (1041, 1041, 1041)  1 = 4 (1041, 1041, 1041, 1041, 1041, 1041)  1 = 4 (1041, 1041, 1041, 1041, 1041, 1041, 1041)  1 = 4 (1041, 1041		A (HHL 1, NCH, NR)   A (HHL 1, NCH, NR)   A (HHL 1, NCH, NR)     U C SOD (A (HR)   A (HHL 1, NCH, NR)     U C SOD (A (HR)   A (HHL 1, NCH, NR)     U C SOD (A (HR)   A (HHL 1, NCH, NR)     U C SOD (A (HR)   A (HR)   A (HR)   A (HR)     U C SOD (A (HR)   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)   A (HR)     U C HR   A (HR)   A (HR)     U C C   A (HR)   A (HR)     U C C   A (HR)     U C C C C   A (HR)     U C C C C C C C C C C C C C C C C C C	1 = A (MKL, NCM, κM) = A (MKL, NK, NF) / NF   VU     1 = A (MKL, NCM, κM) = A (MKL, NK, NF) / NF   VU     1 = A (MKL, NCM, κM) = A (MKL, NK, NF) / NF     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM) = A (MKL, NK, NF)     1 = A (MKL, NCK, KM)     1 = A (MKL, NCK, MK)     1 = A (MK, MK, MK, MK, MK, MK, MK, MK, MK, MK,
		A (HHEL, NCH, KM) = A (MHL, NCM, KM) / NP1 VU     D (C 500 KM+KM) = A (MHL, NCK, KM)     D (C 500 KM+KM) = A (MHL, NCK, KM)     D (C 500 KM+KM) = A (MHL, NCK, KM)     D (C 500 KM+KM) = A (MHL, NCK, KM)     D (C 500 KM+KM) = A (MHL, NCK, KM)     D (C 500 KM+KM) = A (MHL, NCK, KM)     D (C 500 KM+KM) = A (MHL, NCK, KM)     D (C 500 KM+KM) = A (MHL, MCK, KM)     D (C 500 KM+KM) = A (MHL, MCK, KM)     D (C 500 KM+KM) = A (MHK, MCL, MM)     D (C 500 KM+KM) = A (MHK, MCL, MM)     D (C 500 KM+KM, KM, MM, MM, MM, MM, MM, MM, MM, MM,	1 = 4 (HKL, NCM, KM) = 3 (MKL, NCM, KM) / NP 1 VO     1 = 4 (HKL, NCM, KM) = 3 (MKL, NCM, KM)     1 = 4 (HKL, NCM, KM) = 4 (MKL, NCM, KM)     1 = 4 (HKL, NCM, KM) = 4 (MKL, NCM, KM)     1 = 4 (HKL, NCM, KM) = 4 (MK, NCM, KM)     1 = 4 (HKL, NCM, KM) = 4 (MK, NCM, KM)     1 = 4 (HKL, NCM, KM) = 4 (MK, NCM, KM)     1 = 4 (HKL, NCM, KM) = 4 (MK, NCM, KM)     1 = 4 (HKL, NCM, KM) = 4 (MK, NCM, KM)     1 = 4 (HKL, NCM, KM, MK, MK, MK, MK, MK, MK, MK, MK, M
Lie A (Link Link Link Link Link Link Link Link			
Link			
Lind (			A (IHEL, NCH, KM) = A (MHL, NLM, NP) / NP I VU     LatintL **NCH** KM) = A (MHL, NCK*, NM) / NP I VU     LatintL **NCK*, NM)
=			A (IHEL, NEW, KM) = A (NHE, NEM, NH) / NH   NH   NH   NH   NH   NH   NH   NH
1= 4 (MLL **MCM**KM)			
	Late		
Let (Let (Let (Let (Let (Let (Let (Let		A (IMEL NCH, KR) = A (NHE, NCM, KP) / LP (VOI)     La (IMEL NCH, KR) = A (NHE, NCM, KP) / LP (KI) (NEM, KM)     La (IMEL NCK, KR) = A (NHE, NCK, KR) - LP (KI) (NEM, KM)     LA (LA NCK, LR KM) = A (NHE, NCK, KR) - LP (KI) (A LECK, RP)     LA (LA NCK, RR) = A (NHE, NCK, KR)     LA (LA NCK, RR) = A (NHE, NCK, KR)     LA (LA NCK, RR) = A (NHE, NCK, RR)     LA (LA NCK, RR) = A (NHE, RR)     LA (LA NCK, RR) = A (NHE, RR)     LA (LA NCK, RR)	A (IHEL, NCH, KM) = A (NHE, NEM, NH) / NP   VU
= d (HML + NCHO + KH)	Late (Lake)   Lake)   Late (Lake)   Lake)   Late (Lake)   Lake)	A (IMEL ************************************	a (iHCL, NCH, KF) = a (MHC, NCM, KP) / MP   VU     a (iHCL, NCH, KF) = a (MHC, NCM, KP) / MP   VU     b (MC   NCM, NCM) = a (MHC, NCK, NM) - i a (KI, HCK, NM)   COM   MINE   COM   COM   MINE   COM   MINE   COM     MINE   COM   MINE   COM   MINE   COM   MINE   COM     MINE   COM   MINE   COM   MINE   COM   MINE   COM     MC = NC (N, KM)   MCK
	Late (and works)   Late (and works)   Late (and works)	A (IMEL NCH, KPM) = A (NHE, NEW, FPE) / J. P. P. I VO     A (IMEL NCH, KPM) = A (NHE, NEW, FPE) / J. P. P. I VO     La (IMEL NCH, RPM) = A (NHE, NEW, FPE) / J. P. A (KEI, NEW, RPM)     La (SOU A=11, NEW, RPM) = A (NHE, NEW, RPM) = La (KEI, NEW, RPM)     LA (A (LE) A (NHE, NEW, RPM) = A (LE) A	A (144L, NCA, KR) = A (NML, NCA, KM)   LO (KI)   LO (K
L = A (LHEL *NUTH * KP)   L = A (LHEL * NUTH * LHEL		A (IMIC NCH, KM) = A (NHL, NCM, KM) / MP 10     A (IMIC NCM, KM) = A (NHL, NCM, KM) / MP 10     U(C 500 A=1,1)     DUO A (IMIC NCM, KM) = A (NHL, NCK, KM) - 19 A (KI, NCM, KM)     DUO COMITMUS     DUO COMITMU	A (144L, NCA, KR) = A (NHL, NCA, KA) / NP 1 V I     = A (144L, NCA, KR) = A (NHL, NCK, KR) - I PA (KI, HCA, KR)     U(
Late	Late (Late of Late o		A (144L, NCH, KR) = A (NHL, NCH, NH) / NP 1 V U     Latel (Latel ACIDNA   Latel ACIDNA   Late
Late	Latinit : NICHEN	A (IMEL ************************************	A (14KL, NCH, KR) = A (NHL, NCM, KH) / NP 1 V
Later   Late	1 (1 (2 (1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	GUMIL   MICHA   KM   A   MICHA   MIC	A (14KL, NCH, KM) = A (NKL, NCM, KM)   A (14KL, NCH, KM) = A (NKL, NCH, KM) = A (NKL, NCM, KM)   A (NKL, NCM, NCM, MK, NCM, NCM, NCM, NCM, NCM, NCM, NCM, NCM
Late	Latint .u.Ch.   Latint .u.Ch	A (!MEL_NCM_RM) = A (!MEL_NCM_RM)   A (!MEL_NCM_RM)     LOG SOU	A (HKL, NCH, KM) = A (NKL, NCM, KM) / NPI VUI
Latentlandship	I a ( I with wider b)   U   500 N = 1 w   W   500 N   W   W   W   W   W   W   W   W   W	A (HML, NCM, RM) = A (NML, NCM, RM) / NM   NM   NM   NM   NM   NM   NM   NM	
U   S   U   U	Latint   NCM   N	A (!MEL_NCM.RM) = A (!MEL_NCM.RM) / MED 1001  LUG 500 R = R. M.  PLK = MC(LN.RM)  DUU G NET. M.  PLK = MC(LN.RM)  DUU G NIHL MCR.KM) = A (!MEL.NCR.KM) - [ **A (K   **I MCN.RM)    LUG 500 R = R. M.  PLE = MC(LN.RM)  NCN=RC (**KM)  IF (**A SA (**I MCN.RM)) **LI **LI **LI **LI **LI **LI **LI **	
= a (MRI MCGM-KA)	Latint .nCm.nd   Latint .nCm.nd .nd   Latint .nd	GURL   MCM   KM   A   A   A   A   A   A   A   A   A	
= a (wkt.wkm)   bu   bu   bu   bu   bu   bu   bu   b	Lating and a continue of the	GUNTLAND	
= a (wkt * wkm*kh)	Lating   Superior	A	
= a (mkt , mCm , kh)	Lating   Name   Lating   Lat	A   A   A   A   A   A   A   A   A   A	Late   Lunking
Eater   Inch	Latington,   Lat	A	A (INEL, NCM, KM) = A (NKL, NCM, KM)   LOWER   LOWE
	Lating   Supering	A	A (MHL, NCM, KM) = A (MHL, NCM, KM) / MP 1 VU 1  1 = A (MHL, NCM, KM) = A (MHL, NCM, KM) / MP 1 VU 1  5 UU G SON R=14,N  1 LCE = A (MENN, KM) = A (MHL, NCK, KM) - L9 A (KI, MCM, KM)  1 LA MAN = A (MHL, NCK, KM) - L9 A (KI, MCM, KM)  1 LA MAN = A (MHR) = A (MHL, NCK, KM) - L9 A (KI, MCM, KM)  1 LA MAN = A (MHR) = A (MHL, NCK, KM)  1 LA MAN = A (MHR) = A (MHL, NCK, KM)  1 LA MAN = A (MHR) = A (MHR)  1 LUSULV - BLOCK = *, 14,* * LAS! PIVUI IS** E L2*)  1 LUSULV - BLOCK = *, 14,* * LAS! PIVUI IS** E L2*)  1 HE LUKH  1 ENU  1
L=A(AML **ACM**R)		HINTL, NUM, KM = A (NML, NCM, KM) / MPIVUI	A (MHL, NCM, KM) = A (MHL, NCM, KM) / MP1VU1  LEA (MHL, NCM, KM) = A (MHL, NCM, KM) - 19A (K1, MCM, KM)  UG 500 N = M, N  MICK=NC(N, KM)  DUU 500 N = M, N  MICK=NC(N, KM)  NNA=RC(N, KM)  MLOCK = *, 14, * P   VU1   15* * 15* * 12* 5)  HE LUKU  SUHMUN / SETUP/ UH(4), UH(4), UH(4), MP (4), * 1 N   MC (* 4* * 1))  CUMMUN / A A (* 4* * 1) / MC (MC (* * * * 1))  CUMMUN / PARMIL N, NN* NN  NU 300 L=1, NN  NU 100 M=1, NN  NU 100 M=1, NN  SUM=EN(L* M1)
L=A(AML.NCM.NCM.NCM.NCM.NCM.NCM.NCM.NCM.NCM.NCM	1=a(intt.vnCs+Rd)		A (MHL, NCM, KM) = A (MHL, NCM, KM) / MP1VU1     = A (MH, NCM, KM) = A (MHL, NCM, KM) - I = A (KI, MCM, KM)     = A (MH, MCK, KM) = A (MHL, NCK, KM) - I = A (KI, MCM, KM)     = A (MHL, MCK, KM) = A (MHL, NCK, KM) - I = A (KI, MCM, KM)     = A (MHL, MCK, KM) = A (MHL, NCK, KM) - I = A (KI, MCM, MM)     = A (MHM, MCM, KM)     = A (MHM, MCM, KM)     = A (MHM, MCM, KM)     = A (MHM, MCM, MCM, MCM, MCM, MCM, MCM, MCM,
I = A (ANTL + NCM + RA)		A   A   A   A   A   A   A   A   A   A	A (14HL, NCH, κH) = A (NHL, NCH, κH) / NH) / NH
		A   A   A   A   A   A   A   A   A   A	A (14HL, NCM, KM) = A (NHL, NCM, KM) / NPIVUI L=A (NHL, NCM, KM) = A (NHL, NCM, KM) - L*A (KI, NCM, KM) UC 500 N=MN RLN=NC (N+MN) RLN=NC (N+MN) RLN=NC (N+MN) NLN=NC (N+MN) NLN=NC (N+MN) NLN=NC (N+MN) NLN=NC (N+MN) NLN=NC (N+MN) IF (AHS (A (NHN+NCN+KM)) LI 1: 1: 4-10)
L=A (MRL * NCM * KB)		A   A   A   A   A   A   A   A   A   A	A (14HL, NCM, KM) = A (14HL, NCM, KM) / LP (1 V U)  1 = A (14HL, NCM, KM) = A (14HL, NCM, KM)  UG 500 N=HN  NCM (14MC)  NCM (
1 = A (MRL * MCM*K#)  UU	Latient .nc.   Lati		A (14HL, NCM, KM) = A (NHL, NCM, KM) / NP1VU1 L=A (NHL, NCM, KM) = A (NHL, NCK, KM) = 1°A (K1, NCA, KM) DUU SUU K=NC (N+KM) DUU CON   INUE   NCK, KM) = A (NHL, NCK, KM) = 1°A (K1, NCA, KM) NCM=NC (N+KM) NCM=NC (N+MM) NCM=NC (N+MM) NCM (NCM (N+MM) NCM (NCM (N+MM) NCM (NCM (N+MM) NCM (NCM (N+MM) NCM (NCM (NCM (NCM (NCM (NCM (NCM (NCM (
1 = A (MRL * MCM*K#)  U U SOU N = 11*N  NLN = C(CIN.*M)  SOU A (WRL*MCK*KM) = A (MRL*MCK*KM) = 1*A (KI*NCN*KM)  SOU A (WRL*MCK*KM) = A (MRL*MCK*KM) = 1*A (KI*NCN*KM)  NLN = DK (M*KM)  II (AHS SA (MRN*MCN*KM)) * LI*1.*L*10) * KIIL (6*6100) KM*A (MRN*MCN*KM)  NLN = NC (M*KM)  II (AHS SA (MRN*MCN*KM)) * LI*1.*L*10) * KIIL (6*6100) KM*A (MRN*MCN*KM)  II (AHS SA (MRN*MCN*KM)) * LI*1.*L*10) * KIIL (6*6100) KM*A (MRN*MCN*KM)  KE IUKH  KE	Later   Late		
	Latient .ncm.ncm.ncm.ncm.ncm.ncm.ncm.ncm.ncm.ncm		A
L=A(WHL *NCM * KA)	Latinki   Wichels   Michaels		A (14KL, NCM, κM) = A (NHL, NCM, κM) / NP1VUI  1 = A (4NHL, NCM, κM)
Lie A (WHL + WCM + KA)	F=4 (WHL * WCM* NA)	A (MML, NCM, KM) = A (MML, NCM, KM) / MM   LE A (MML, NCM, KM) = A (MML, NCM, KM)   LE A (MML, NCM, MML, NCM, NCM, NCM, NCM, NCM, NCM, NCM, NCM	
L=A(WHL+NCM+KA)	1=a(wkt * wcm* κ kt)  UG 500 κ= η, ν  UG 500 κ γ  UG 500 κ= η, ν  UG 6 γ  UG 7 γ  UG	A (MML, NCM, KM) = A (MML, NCM, KM) / MM   Let (MML, NCM, KM) = A (MML, NCM, KM)   Let (MM, KM	
L=A (RRIL - NG.M-KH)	Leaturian   Leat	LadinkLinchikm) = a (wkLincm, km) / mb 1001	A (HML, NCM, KM) = A (NML, NCM, KM) / NP1VUI
L=A(RRL -NCM-KH)	E=4 (NML NUCM+R)	A (MML, NCM, KM) = A (MML, NCM, KM) / MM   LE (MML, NCM, KM) = A (MML, NCM, KM) = A (MML, NCM, KM)   LE (MML, NCM, KM) = A (MML, NCK, KM)   LE (MML, NCK, MML, NCK, MML, NCK, MML, NCK, MML, NCK, MML, MML, MML, MML, MML, MML, MML, MM	A (144L, NCM, KM) = A (N4L, NCM, KM) / NP1VUI     L=A (144L, NCM, KM)     L=A (144L, NCM, KM)     L=A (144L, NCM, KM)     NCM   LO SOO
L=A (RRIL + NGCM+KA)	1=4 (10) (1-1) (1		A (HML, NCM, KM) = A (NML, NCM, KM) / NP1VUI
L=A (WRL + NGM + KA)	E=4 (NML NUCM+R)	A (IMPL, NCM, KM) = A (MML, NCM, KM) / MM   MML   MCM, KM   MCM, MCM, MCM, MCM, MCM, MCM, MCM, M	A (HRL, NCM, KM) = A (MRL, NCM, KM) / NP1VUI  L=A (MRL, NCM, KM) = A (MRL, NCK, KM) - 1*A (KI, NCK, KM)  NCLN=NC (M=M, NN)  NCLN=NC (M, KM)  SUU CONIINUE  NKN=ER (M, KM)  IF (AHS(A(MRN, NCN, KM)), LI-1.t - 10) "KIIE (6+6100) KM, A (NKN, NCN, KM)  NCN=NC (M, KM)  IF (AHS(A(MRN, NCN, KM)), LI-1.t - 10) "KIIE (6+6100) KM, A (NKN, NCN, KM)  IF (AHS(A(MRN, NCN, KM)), LI-1.t - 10) "KIIE (6+6100) KM, A (NKN, M)  IF (AHS(A(MRN, NCN, KM)), LI-1.t - 10) "KIIE (6+6100) KM, A (NKN, M)  KE IUKRI  ENU  SUUHOUIINE HEIASV (KM)  IHIS SUMMON /SETUD/ UH(4), UHX(4), FF (4), AJA(4,4)  CUMMON /AX A (4,4,1) / HY D (2,4,1) / NCX (4,4))  CUMMON /AX A (4,4,1) / HY D (2,4,1) / NCX (4,4))  CUMMON /AX A (4,4,1) / NC/ NC (4,4))  SULVE Y IN Y * (U* <sub>U</sub> ) = H
L=A (LNKL NLCM * KM)	E= (intl. inCm.kA)	A (IMPL, NCM, KM) = A (NML, NCM, KM) / NM   IND   IN	Halinking
L=A (LWLL - N.C.M N.C.M.	F= (intl. intm.kA)	A (IME, NCM, KM) = A (NRE, NCM, KM) / NP 1 VU     B (IME, NCM, KM) = A (NRE, NCM, KM) / NP 1 VU     D (0 500 N = 1) N	A (14KL, NCM, KM) = A (NKL, NCM, KM) / NP1VUI LEA (NRL, NCM, KM) = A (NKL, NCK, KM) - 1*A (K 1. NCK, KM) RICK=NC(N, KM) BOUD A (NHL, NCK, KM) = A (NKL, NCK, KM) - 1*A (K 1. NCK, KM) RICK=NC (N, KM) BOUD A (NHL, NCK, KM) = A (NKL, NCK, KM) - 1*A (K 1. NCK, KM) RICK=NC (NKM) BOUD FURMAT(* LUSOLV - RLOCK =*,14,* PIVUI AI EUN HOJ=*,12,* IS*,E12.5) RE LUKH END SUBHOUTINE HETASV(KM) IHIS SUMMON / SETUP/ UH(4), UHX(4), FF (4), AJA(4,*) COMMON / SETUP/ UH(4), UHX(4), FF (4), AJA(4,*) COMMON / SETUP/ UH(4), UHX(4), FF (4), AJA(4,*) COMMON / PARMI/ N, NP, NN COMMON / PARMI/ N, NP, NN COMMON / PARMI/ N, NP, NN COMMON / PARMI/ N, NP, NN
L=A (LWLL + NLGM + NA)	E= (iwit .nicm.kd)	Hadinki, NCM, KM) = A (NKI, NCM, KM) / NM   NM   NM   NM   NM   NM   NM   NM	HILLINGH.KM
= A (LNKL + NCM + KH)	E= (intl. inCm.kA)	# (!ML.,NCM,KM) = A (NML,NCM,KM) / NF   LIVUI	A (IMEL, N.C.M., KM) = A (NMEL, N.C.M., KM), ZMP 1 V U I  1 = A (IMEL, N.C.M., KM) = A (NMEL, N.C.M., KM)  5 U
= a (	= a (int incm = k)	A (IME, NCM, KM) = A (NME, NCM, KM) / NMM   LOUGH	Harthone
= a (	= A (INTL + NICM +	A (IMK, NCM, KM) = A (NKL, NCM, KM) / NM   L (IMK, NCM, KM)     L = A (NKL, NCM, KM)     U	Harthander   Har
= a (	= A (INTR   NICK	A	A (14KL, NCM, KM) = A (NKL, NCM, KM) / NP 1 V U I  1 = A (14KL, NCM, KM) = B (NKL, NCK, KM) - I*A (KI*NCK, KM)  1 = A (14KL, NCM, KM)  1
L=a(wkl.wcm.kd)		A (HML, NCM, κM) = A (MML, NCM, KM) / LMP 1 VOI   1 = A (HML, NCM, κM) = A (MML, NCM, KM)   1 U	A (!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
L=a(wkl.wcm.kd)	F=4 (NML.NCM.NF)	######################################	A (14KL, NCM, KM) = A (NKL, NCM, KM) / NP 1 VU I  1 = A (14KL, NCM, KM)  1 = A (14KL, NCM, KM)  1
= a ( m k   + m k m k m k m k m k m k m k m k m k m	F=4 (NML NCM-NF)	# (#ML, NCM, KM) = A (MML, NCM, KM) / MP 1 vol    1 = A (MML, NCM, KM) = A (MML, NCM, KM) / MP 1 vol    10	A (HML, NCM, KM) = A (MML, NCM, KM) / MP 1 V U I  1 = A (MML + NCM+KM)  U G 500 R = M, N  PICR = NC (R, NM)  PICR = NC (R, NM)  PICR = NC (R, NM)  NCN = NC (R, NM)  I f (AHS / A (MM) NCN+KM)  I f (AHS / A (MN) NCN+KM)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM(4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / SETUP/ UM (4) · UHX (4) · FF (4) · A JA (4+4)  COMMON / UMX (4) · FF (4) · A JA (4+4)  COMMON / UMX (4) · FF (4) · A JA (4+4)  COMMON / UMX (4) · FF (4) · A JA (4+4)  COMMON / UMX (4) · FF (4) · A JA (4+4)
= a ( m k   . m k k k k k k k k k k k k k k k k k k	1=4 (NYL.NCM.KA) UU 500 N=M.N UU 500 N=M.N NCN=NC(N.KM)  000 A(NYL.NCK.KM)=A(NYL.NCK.KM)-1*A(K1.NCN.KM)  000 A(NYL.NCK.KM)=A(NYL.NCK.KM)-1*A(K1.NCN.KM)  000 A(NYL.NCK.KM)  000 A(NYL.NCK.KM)  000 A(NYL.NCK.KM)  14 (AHS.A(N.KM)  15 (AHS.A(N.KM)  16 (AHS.A(N.KM)  17 (AHS.A(N.KM)  18 (AHS.A(N.KM)  18 (AHS.A(N.KM)  18 (AHS.A(N.KM)  18 (AHS.A(N.KM)  18 (AHS.A(N.KM)  18 (AHS.A(N.KM)  19 (AHMA)  19 (A	# (MRL, NCM, KM) = A (MRL, NCM, KM) / MP 1 VU I  1	# (HML, NCM, KM) = A (MML, NCM, KM) / MP 1 V U I  1 = A (MML, NCM, KM) = A (MML, NCK, KM) - I * A (K I * NCK, KM)  1
= a (wkl * ncm*nka)	1=4 (NYL.NCM.KA)  UG 500 N=1,N  NUC	A (MML,NCM,KM) = A (MML,NCM,KM) / MP   VUI     L = A (MML,NCM,KM) = A (MML,NCM,KM)     UG 500 K=M,N     NCM=NC(N,KM)     NC	A (HML,NCM,KM) = A (MML,NCM,KM)/MP_VUI L=A(MML,NCM,KM) UG 500 R=M,N PICR=NC(R,RM) BUO A(MML,NCR,KM) = A(MML,NCK,KM) - I * A(KI,NCR,KM) BUO A(MML,NCN,KM) = A(MML,NCK,KM) - I * A(KI,NCR,KM) BUO CON I IMUE NEND FURMAT (* LUSOLV - RLOCK =*,14,* PIVUI AI EUN NO-=*,12,* IS*,E12.5) HE   UKM   CHENCOLINE HE   ASUCK =*,14,* EASI   PIVUI   IS*,E12.5) HE   UKM   END
L=a(wkL *NCM*KA)	L=a (wkL .wcm.kA)	A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VOI 1 = 4 (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VOI 1 UG 500 K=M, N 1 NCK=NC (K, KM) 1 NCK=NC (K, KM) 1 NCM=NC (M, KM) 1 NCM (M, KM) 1 N	A (MML, NCM, KM) = A (MML, MLM, NM) / MP LVUI 1 = A (MML, NCM, KM) = A (MML, MLM, NM) / MP LVUI UG 500 R=M,N NLN=NC (N, NM) BUU A (MML, NMCN, KM) = A (MML, NCK, KM) - 1*A (KI, NCK, KM) BUU CONI INUE NKN=KR(N, NM) NLN=KR(N, KM) IF (AHS (A (MRN, NCN, KM)) . LI-1.4-10) wHile (b, bloo) KM, A (NKN, NCN, KM) NLN=KR(N, KM) IF (AHS (A (MRN, NCN, KM)) . LI-1.4-10) wHile (b, bloo) A (M, A) (M, KM) IF (AHS (A (MRN, NCN, KM)) . LI-1.4-10) wHile (b, bloo) A (M, A) (M, KM) IF (AHMAI (* LUSOLV - BLOCK =*,14,* PIVUI AIS*,E12.5) KE LUKN END SUBMOUTINE HETASV (KM) IHIDIAGONAL NATHIN A COMMON / SETUP/ UH(4),UHX(4),FF (4),AJA(4,4)
= a (wkl . wcm.kk)	L=a(INKL*NCM*RP)	A (IMEL, NCM, KM) = A (MME, NCM, KM) / INPIVUI     L= A (IMEL, NCM, KM) = A (MME, NCM, KM)     U	A (MML, NCM, KM) = A (MML, NCM, NM) / MP 1 VUI  1 = A (MML, NCM, KM) = A (MML, NCM, KM) / MP 1 VUI  500 R = M, NM  NCM = CM, CM, MM)  500 A (MML, NCM, KM) = A (MML, NCK, KM) - 1 * A (K   · NCM, KM)  NCM = CM, CM,
= a ( wr L · w C m · k M )	L=4 (MKL+NCM+KA)  UG 500 K=M+N  MCK=NC(N+KM)  500 A(NKL+NCK+KM) = A(NKL+NCK+KM) - 1*A(K1+NCK+KM)  MCK=NC(N+KM)  500 A(NKL+NCK+KM)  MCK=NC(N+KM)  MCK=NC(N+KM)  MCK=NC(N+KM)  MCK=NC(N+KM)  MCK (N+KM)	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1001  1 = A (MKL, NCM, KM)  1 = A (MKL, NCM, KM)  1 = A (MKL, NCM, KM)  500 A (MKL, NCK, KM)  600 C ON   IMUE  600 C ON   IMUE  600 C ON   IMUE  600 F ON MANA (MRN)  600 F ON M	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP 1 VUI L= A (MKL, NCM, KM) LUG 500 R= M, N NCM = NC (R, KM) 500 A (MKL, NCK, KM) = A (MKL, NCK, KM) - I * A (KI, NCK, KM) NCM = NC (R, KM) NCM = NC (R, KM) NCM = NC (R, KM) IF (AHS (A (MRN, NCM, KM)) - LI · I · I · I · I · I · I · I · I · I
L=a(nRL.NCM.KA)  UG 500 R=N.N  NCR=NC(R.KM)  SUU A(NKL.NCR.KM) = A(NKL.NCR.KM) - 1*A(KI.NCR.KM)  SUU CON IINUE  NKN=KK(N.KM)  IF (AHS (A (RN.N.NCN.KM)) . LI.1.t - 10) wKI ! E (b.b100) KM.A (NKN.NCN.KM)  IF (AHS (A (RN.N.NCN.KM)) . LI.1.t - 10) wKI ! E (b.b100) KM.A (NKN.NCN.KM)  IF (AHS (A (RN.N.NCN.KM)) . LI.1.t - 10) wKI ! E (b.b100) KM.A (NKN.NCN.KM)  IF (AHS (A (RN.N.NCN.KM)) . LI.1.t - 10) wKI ! E (b.b100) KM.A (NKN.NCN.KM)  IF (AHS (A (RN.N.NCN.KM)) . LI.1.t - 10) wKI ! E (b.b100) KM.A (NKN.NCN.KM)  KE ! UKR  ENU  SUUMOUI INE HE IASV (KM)  IMIS SUMMOUI INE SOLVES F UR BE IA IN IMF LU-DECUMPOSITION UF IME ALUCR  IMIDIAGUNAL MAIKIA	L=a(wkl.ncm.ncm.ncm.ncm.ncm.ncm.ncm.ncm.ncm.ncm	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MPIVUI L=A (MKL, NCM, KM) = A (MKL, NCK, KM) - I*A (KI, NCK, KM)  DUD 500 N=11,N  PLCN=NC (N, KM)  DUD 40N LUNE, KM) = A (MKL, NCK, KM) - I*A (KI, NCK, KM)  DUD 600 A (MKL, NCK, KM) = A (MKL, NCK, KM) - I*A (KI, NCK, KM)  NCN=NC (N, KM)  IF (AHS (A (MRN, NCN, KM)) . LI. I. I	A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP 1 VUI  L=A (WKL, NCM, KM)  UG 500 R=M,N  NLN=NC (R, KM)  500 A (WKL, NCK, KM) = A (MKL, NCK, KM) - I*A (KI, NCK, KM)  500 CON   IMUE  NKN=KR (N, KM)  NLN=NC (N, KM)  IF (AHS (A (MRN, NCN, KM))  IF (AHS (A (MRN, MRN, MRN, MRN, MRN, MRN, MRN, MRN,
H=A(WRL.NCM.KA)  UG 500 K=M.N  NCN=NC(R.KM)  500 A(WRL.NCK.KM) = A(MKL.NCK.KM) - 1*A(KI.NCK.KM)  500 CON; INUE  NKN=KR(N.KM)  NCN=NC(N.KM)  NCN=NC(N.KM)  IF (AHS (A(MRN.NCN.KM)).LI.1.t-10) wRITE (6.5100) KM.A(NKN.NCN.KM)  NCN=NC(N.KM)  IF (AHS (A(MRN.NCN.KM)).LI.1.t-10) wRITE (6.5100) KM.A(NKN.NCN.KM)  IF (AHS (A(MRN.NCN.KM)).LI.1.t-10) wRITE (6.5100) KM.A(NKN.NCN.KM)  IF (AHS (A(MRN.NCN.KM)).LI.1.t-10) wRITE (6.5100) KM.A(NKN.NCN.KM)  KELUKU  KELUKU	L=a(wkl.ncm.n) UG 500 R=n,N NLN=NC(n.kM) 500 A(Wkl.nck.kM)=A(Nkl.NCK.kM)-1*A(Ki.NCK.kM) NLN=NC(n.kM) NNN=ER(N.MM) NCN=NC(n.kM) NCN=NC(n.kM) IF (AHS(a(MRN.NCN.KM)).LI.1.t-10) wRITE (6.6100) KM.A(NKN.NCN.KM) NCN=NC(n.kM) IF (AHS(a(MRN.NCN.KM)).LI.1.t-10) wRITE (6.6100) KM.A(NKN.NCN.KM) IF (AHS(a(MRN.NCN.KM)) IF (AHS(a(MRN.NCN.KM)).LI.1.t-10) wRITE (6.6100) KM.A(NKN.NCN.KM) IF (AHS(a(MRN.NCN.KM)) IF	A (MML,NCM,KM) = A (MML,NCM,KM) / MPIVUI  1 = A (MML,NCM,KM)  1	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP 1 VUI  L=A (MKL, NCM, KM)  UG 500 R=M,N  RICR=NC (R, KM)  500 A (MKL, NCK, KM) = A (MKL, NCK, KM) - I*A (KI, NCK, KM)  NKM=NC (R, KM)  NKM=K (N, KM)  NKM=K (N, KM)  IF (AHS (A (MKN, NCN, KM)) . LI.11.t - 10) *KIIE (5, 5100) KM, A (NKN, NCN, KM)  NCM=NC (N, KM)  IF (AHS (A (MKN, NCN, KM)) . LI.11.t - 10) *KIIE (5, 5100) KM, A (NKN, NCN, KM)  IF (AHS (A (MKN, NCN, KM)) . LI.11.t - 10) *KIIE (5, 5100) KM, A (NKN, NCN, KM)  IF (AHS (A (MKN, NCN, KM)) . LI.11.t - 10) *KIIE (5, 5100) KM, A (NKN, NCN, KM)  KE LUKH  ENU  SUUKHOUIINE HE IASV (KM)  IMIS SUUKHOUIINE BE IASV (KM)  IMIS SUUKHOUIINE SOLVES FUR BE IA IN IMF LU-DECUMPOSITION OF IME ALUCA
F=A(WRL +NCM+KA)	1=4 (MML·NCM·NG)  UC 500 R=M·N  NLN=NC(N·NM)  SUU A(MML·NCN·NM)  SUU A(MML·NCN·NM)  SUU A(MML·NCN·NM)  SUU A(MML·NCN·NM)  NLN=NC(N·NM)  NLN=NC(N·NM)  NLN=NC(N·NM)  NLN=NC(N·NM)  IF (aHS(a(MMN·NCN·NM)).LI·I·E-I0) wRITE(b·DIO) KM·A(NKN·NCN·KM)  KE IUKRI  END  SUBMOUTINE HETASV(KM)  IMIS SUBMOUTINE SOLVES FUR BETA IN THE LU-DECOMPOSITION OF THE ALOCN  IMIS SUBMOUTINE MATHIA	# (#ML, NCM, KM) = A (#ML, NCM, KM) / RM   1	A (WML, NCM, KM) = A (WML, NCM, KM) / MP 1 VUI 1 = A (WML, NCM, KM) = A (WML, NCM, KM) / MP 1 VUI 500 N = M, N NCM = NC (N, KM) 500 A (WML, NCM, KM) = A (MML, NCK, KM) - 1 * A (K   · NCM, KM) NCM = NC (N, KM) NCM = NCM = NCM   N
F=A(WRL +NCM+KA)	Fa(MML:NCM:NCM:NCM:NCM:NCM:NCM:NCM:NCM:NCM:NCM	# (INKL, NCM, KM) = A (NKL, NCM, KM) / NP 1 VOI    1 = A (NKL, NCM, KM) = A (NKL, NCK, KM) - I * A (KI, NCK, KM)    1	A (WML, NCM, KM) = A (WML, NCM, KM) / MP 1 VUI  1 = A (WML, NCM, KM) = A (WML, NCM, KM) / MP 1 VUI  5 0 0
LEATINGCM. N.CM. N.	L= A (WRL . NCM	# (WRL,NCM,KM) = A (WRL,NCM,KM) / PP1V01  1 = A (WRL,NCM,KM) = A (WRL,NCM,KM)  500 A (WRL,WCK,KM) = A (WRL,NCK,KM) - 1*A (K1,NCK,KM)  500 A (WRL,WCK,KM) = A (WRL,NCK,KM) - 1*A (K1,NCK,KM)  600 CON; INUE  NAN=AR((N,KM)  IF (AHS (A (MRN,NCN,KM)),L1.1.t-10) WRITE (6:6100) KM:A (NKN,WCN,KM)  IF (AHS (A (MRN,NCN,KM)),L1.1.t-10) WRITE (6:6100) KM:A (NKN,WCN,KM)  IF (AHS (A (MRN,MCN,KM))  IF (AHS (A (MRN,MCN,KM))  KE 1UKM  KE 1UKM  END  SUBMOUTINE HETASV(KM)  IMIS SUMMOUTINE BETASV(KM)  IMIS SUMMOUTINE BETASV(KM)	A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP 1 VUI L=A (WKL, NCM, KM) UG 500 N=M, N  NCK=NC (N, KM)  NCK (
H=A(WML.NCM.KA)  UG 500 K=M.N  NLK=NC(N.KM)  500 A(WKL.NCK.KM) = A(NKL.NCK.KM) - 1*A(KI.NCK.KM)  600 CON I INUE  NKN=KK(N.KM)  IF (AHS (A(MKN.NCN.KM)) .Ll.i.t-10) "KI I E (6.6100) KM.A(NKN.NCN.KM)  NLN=NC (N.KM)  IF (AHS (A(MKN.NCN.KM)) .Ll.i.t-10) "KI I E (6.6100) KM.A(NKN.NCN.KM)  IF (AHS (A(MKN.NCN.KM)) .Ll.i.t-10) "KI I E (6.6100) KM.A(NKN.NCN.KM)  IF (AHS (A(MKN.NCN.KM)) .Ll.i.t-10) "KI I E (6.6100) KM.A(NKN.NCN.KM)  KE I UKM  KE I UKM  KE I UKM  END  SUBMOUTINE HETASV(KM)  IMIS SUMMOUTINE SOLVES FUR BETA IN THE LU-U-DECUMPOSITION OF THE ALOCN	1=A(INKL.NCM.KA)  UG 500 A(MKL.NCK.KM)  BUU 500 A(MKL.NCK.KM)  BUU CONIINUE  NAMBARK(N.KM)  IF (AHS (A(MKN.NCN.KM))  IF (	# (WRL,NCM,KM) = # (WRL,NCM,KM) / PPIVUI  1 = # (WRL,NCM,KM) = # (WRL,NCK,KM) -   # (KI,NCK,KM)  1	# (WML, NCM, KM) = A (WML, NCM, KM) / MP 1 VUI 1 = A (WML, NCM, KM) = A (WML, NCK, KM) = 1 * A (K 1 · NCK, KM)  UG 500 K = M, N  NCK = NC (K, KM)  DOU CON   INUE  NAN = A (WKL, NCK, KM) = A (WKL, NCK, KM) = 1 * A (K 1 · NCK, KM)  NCK = NC (M, KM)  If (AHS (A (WKN, NCN, KM))
L=a(nkl.nCm.kA)	L=A(INKL.NCM.NEM)	# (WRL, NCM, KM) = A (WRL, NCM, KM) / MP 1 VOI 1 = A (WRL, NCM, KM) = A (WRL, NCK, KM) = 1 * A (KI, NCK, KM) 100 500 K = M, N NICK = NC (N, KM) = A (WRL, NCK, KM) = 1 * A (KI, NCK, KM) NICK = NC (N, KM) = A (WRL, NCK, KM) = A (MR, KM) = A (WRN, MCN, KM) NON = NC (N, KM) IN (N = NC (N, KM)	A (WAL, NCM, KM) = A (WAL, NCM, KM) / MP 1 VUI  1 = A (WAL, NCM, KM)  1 = A (WAL, WCK, WCK, WCK, WCK, WCK, WCK, WCK, WCK
DEA (NRL - NCM - NR)	=	A (MRL,NCM,KM) = A (MML,NCM,KM) / MPIVUI  1=A (MML,NCM,KM)  10 500	A (MML, NCM, KM) = A (MML, NCM, KM) / MP 1 VUI 1=A (MML, NCM, KM) 100 500 K=11,N 100 500 K=11,N 100 500 K=11,N 100 500 K=11,N 100 500 K=11,N 100 500 K=11,N 100 600 INUE 100 NNN=NC (N, KM) 100 100 FURMAI (* LUSOLV - RLOCK =*,14,* PIVUI AI EUN NO.=*,12,* IS*,EIZ*5) 100 6100 FURMAI (* LUSOLV - BLOCK =*,14,* LASI PIVUI IS*,EIZ*5) 100 KE;UKM 100 FURMAI (* LUSOLV - BLOCK =*,14,* LASI PIVUI IS*,EIZ*5) 100 FURMAI (* LUSOLV - BLOCK =*,14,* LASI PIVUI IS*,EIZ*5) 100 FURMAI (* LUSOLV - BLOCK =*,14,* LASI PIVUI IS*,EIZ*5) 100 FURMAI (* LUSOLV - BLOCK =*,14,* LASI PIVUI IS*,EIZ*5)
	== (LN   LN   LN   LN   LN   LN   LN   LN	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP) / MP) 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	A (MML, NCM, KM) = A (MML, NCM, KM) / MP   VUI    1 = A (MML, NCM, KM) = A (MML, NCK, KM) - I*A (KI, NCA, KM)  1
L=a(wkL * NCM * KA)	=	A (HKL, NCM, KM) = A (MKL, NCM, KM) / LP 1 VOI LE A (MKL, NCM, KM) = A (MKL, NCK, KM) - I * A (KI, NCK, KM) DUO 500 N=M,N MCN=NC (N, KM) DUO CUNIINUE NKN=KK (N, NM) NCN=KK (N, NM) NCN=KK (N, NM) IF (AHS (A (MKN, NCN, KM)) - LI · I · E - I 0) WKI IE (6 · 6 I 0 0) KM, A (NKN, NCN, KM) IF (AHS (A (MKN, NCN, KM)) - LI · I · E - I 0) WKI IE (6 · 6 I 0 0) KM, A (NKN, NCN, KM) A C A C C C C C C C C C C C C C C C C C	A (IMEL, NCM, KM) = A (NKL, NCM, KH) / LP 1 VUI  L=A (INKL, NCM, KH)  UG 500 N=M,N  NCN=NC(N, KM)  NCN=NC(N, KM)  A (NKL, NCK, KM) = A (NKL, NCK, KM) - I * A (K   · NCK, KM)  NCN=NC (N, KM)  NCN=NC (N, KM)  If (AHS (A (NKN, NCN, KM)) . LI · I · E - I 0) * KI   E (b · b I 0 0) KM, A (NKN, NCN, KM)  NCN=NC (N, KM)  If (AHS (A (NKN, NCN, KM)) . LI · I · E - I 0) * KI   E (b · b I 0 0) KM, A (NKN, NCN, KM)  If (AHS (A (NKN, NCN, KM)) . LI · I · E - I 0) * KI   E (b · b I 0 0) KM, A (NKN, NCN, KM)  If (AHS (A (NKN, NCN, KM)) . LI · I · E - I 0) * KI   E (b · b I 0 0) KM, A (NKN, NCN, KM)  KE   UKN  KE   UKN  EMI)  SUUMOUIINE HE IASV (KM)
L=a(wkt.ncm.kh)	= a (mmt . mcm . km)	A (MKL, NCM, KM) = A (MKL, NCM, NF) / nF 1 VO 1  L= A (MKL, NCM, KM) = A (MKL, NCK, KM) - 1 * A (K 1 · NCK, KM)  DO 500 R= M, N  RICR=NC (N, KM)  BOU CON   INUE  NAN=ER (N, NM)  NCN=NC (N, KM)  IF (AHS (A (MRN, NCN, KM)), L1 · 1 · 1 · 1 · 1 · 1 · 1 · 1 · 1 · 2 · 1 · 2 · 1 · 2 · 1 · 2 · 1 · 2 · 1 · 2 · 1 · 2 · 1 · 2 · 2	A (HML,NCM,KM) = A (MML,NCM,KM) / LP 1 VUI LEA (MML,NCM,KM) DO 500 N=M,N BLOCK = MC(N,KM) BLOCK = MC(N,KM)
L=a(WRL.NCM.KA)	= a (mkl .ncm.kl)	A (WKL, NCM, KM) = A (WKL, NCM, NF) / nF 1 VO 1  L= A (WKL, NCM, KM) = A (WKL, NCK, KM) - 1*A (KI, NCK, KM)  DU	A (MKL,NCM, KM) = A (NKL,NCM, NF) / NF 1 VUI  L= A (NKL,NCM, KM)  UG 500 N=M,N  NCN=NC (N, KM)  SOU A (MKL,NCK, KM) = A (NKL,NCK, KM) - I*A (KI,NCK, KM)  NCN=NC (N, KM)  NKN=NC (N, KM)  IF (AHS (A (M, KM))  IF (AHS (A (
		A (WKL, NCM, KM) = A (WKL, NCM, KM) / MPIVUI  LEA (WKL, NCM, KM)  UG 500 K=M, N  MICK=NC (K, KM)  MICK=NC (M, KM)  MICK=NC (M	A (MKL,NCM, KM) = A (NKL,NCM, NH) / TH   VUI   L=A (MKL,NCM, KM)   L=A (MKM, MK)   L=A (MK
		A (WKL, NCM, KM) = A (WKL, NCM, KM) / MPIVUI  1 = A (WKL, NCM, KM) = A (WKL, NCM, KM) - I * A (K I * (NCM, KM))  500 A (WKL, NCK, KM) = A (WKL, NCK, KM) - I * A (K I * (NCM, KM))  600 CON I I NUE  WAN = F.K (N, KM)  I F (AHS (A (WKN, NCM, KM)) - LI * I * * * * I * * * * I * * * I * * * I * * * I * * * I * * * I * * * I * * * I * * * I * * * I * * * I * * * I * * * I * * * I * * * I * * * I * * I * * I * * I * * I * I * * I	A (NKL, NCM, KM) = A (NKL, NCM, KM) / LP 1 V U I  L=A (NKL, NCM, KM) = A (NKL, NCK, KM) - I * A (KI, NCK, KM)  DU SOU REMAIN  NCN=NC (N, KM)  A (NKL, NCK, KM) = A (NKL, NCK, KM) - I * A (KI, NCK, KM)  NCN=NC (N, KM)  NCN=NC (N, KM)  IF (AHS (A (MRN, NCN, KM) ), LI · I · E - I 0) WRITE (6 · 6 I 00) KM, A (NKN, NCN, KM)  IF (AHS (A (MRN, NCN, KM) ), LI · I · E - I 0) WRITE (6 · 6 I 00) KM, A (NKN, NCN, KM)  IF (AHS (A (MRN, NCN, KM) ), LI · I · E - I 0) WRITE (6 · 6 I 00) KM, A (NKN, NCN, KM)  KE I UKM  KE I UKM  END
L=a(nRL *NCM*KP)	L=4 (uRL .uCm.kA)	A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP1001  LEA (WKL, NCM, KM)  DG 500 K=M,N  NCK=NC(K, KM)  DO 4 (WKL, NCK, KM) = A (NKL, NCK, KM) - 1*A (KI, NCK, KM)  DO CON I INUE  NKN=EK(N, NM)  NCN=NC(N, KM)  IF (AHS (A (MRN, NCN, KM)) - LI - 1 - 1 0) WKI IE (6, 5100) KM, A (NKN, NCN, KM)  NCN=NC(N, KM)  IF (AHS (A (MRN, NCN, KM)) - LI - 1 - 1 0) WKI IE (6, 5100) KM, A (NKN, NCN, KM)  ACN EURM I (* LUSOLV - RLOCK = *, 14, * PIVUI AI EQN NO.= *, 12, * IS* + LI - 1 - 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1	A (NKL, NCM, KM) = A (NKL, NCM, KM) / LP 1001  LEA (NKL, NCM, KM)  UG 500 K=M,N  NCK=NC (K, KM)  DO 4 (NKL, NCK, KM) = A (NKL, NCK, KM) - I * A (K I · (NCK, KM))  BOU CON I I NUE  NKN=KK (N, KM)  IN (AHS (A (MKN, NCN, KM)), LI · I · E - I 0) WHITE (6 · 6 I 00) KM, A (NKN, NCN, KM)  IN (AHS (A (MKN, NCN, KM)), LI · I · E - I 0) WHITE (6 · 6 I 0) KM, A (NKN, NCN, KM)  IN (AHS (A (MKN, NCN, KM)), LI · I · E - I 0) WHITE (6 · 6 I 0) KM, A (NKN, NCN, KM)  IN (AHS (A (MKN, NCN, KM)), LI · I · E - I 0)  KE I UKM  KE I UKM  KE I UKM
F=		# (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1901  UG 500 K=M,N  MCK=NC(N, KM)  BOU CON I INUE  NKN=K(N, KM)  NKN=K(N, KM)  I (AHS(A (MKN, NCN, KM)) . L1.1.t-10) wKllt(b, bloo) KM, A (NKN, MCN, KM)  NCN=NC(N, KM)  I (AHS(A (MKN, NCN, KM)) . L1.1.t-10) wKllt(b, bloo) KM, A (NKN, MCN, KM)  NCN=NC(N, KM)  H (AHS(A (MKN, NCN, KM)) . L1.1.t-10) wKllt(b, bloo) KM, A (NKN, MCN, KM)  NCN=NC(N, KM)  H (AHS(A (MKN, NCN, KM)) . L1.1.t-10) wKllt(b, bloo) KM, A (NKN, MCN, KM)  NCN=NC(N, KM)  H (AHS(A (MKN, MCN, KM)) . L1.1.t-10) wKllt(b, bloo) KM, A (NKN, MCN, KM)  KE LUSOLV - BLOCK = *, 14,* LASI PIVUT IS**E12.5)  KE LUKR	A (WKL, NCM, KM) = A (WKL, NCM, NF) / HP 1 VUI L= A (WKL, NCM, KM) = A (WKL, NCK, KM) - I * A (KI, NCR, KM) DUC 500 R=M,N RICHENCIN, KM) = A (WKL, NCK, KM) - I * A (KI, NCR, KM) DUC 500 R=M,N RICHENCIN, KM) = A (WKL, NCK, KM) - I * A (KI, NCR, KM) NCN=NC(N, KM) IF (AHS (A (MRN, NCN, KM)) - LI-I-E-10) wH   LCO+D100) KM, A (NKN, NCN, KM) NCN=NC(N, KM) IF (AHS (A (MRN, NCN, KM)) - LI-I-E-10) wH   LCO+D100) KM, A (NKN, NCN, KM) A LOH I (HISOLV - RLOCK = *, 14, * PIVUI A LON NO=*, 12, * IS*, E LC.5) KE 1 UKN
	L=4 (LIKE)	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1VU!  LEA (MKL, NCM, KM)  DG 500 K=M,N  FICK=NC(N, KM)  DOU CON   IMUE  NKN=K(N, KM)  NCN=NC(N, KM)  IF (AHS (A (MRN, NCN, KM)), L1.1.6-10) WRITE (6.6100) KM, A (NKN, NCN, KM)  IF (AHS (A (MRN, NCN, KM)), L1.1.6-10) WRITE (6.6100) KM, A (NKN, NCN, KM)  ALOCK = *, 14,* FIVUI AI EUN NO.=*, 12,*  6100 FUMMAT(* LUSOLV - BLOCK = *, 14,* LASI FIVUI IS*, E12.5)  HELUKH	A (HKL, NCM, KM) = A (NKL, NCM, NF) / HP 1 VO I  LEA (INKL, NCM, KM) = A (NKL, NCK, KM) - I * A (K I * (NCK, KM))  DU SOU A (NKL, NCK, KM) = A (NKL, NCK, KM) - I * A (K I * (NCK, KM))  DUU CON I INUE  NAN=AR (N, AM)  NCN=NC (N, KM)  IF (AHS (A (MRN, NCN, KM)) . LI · I · I · I · I · I · I · I · I · I
Leature   NEW		A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1001  LE A (MKL, NCM, KM)  UG 500 K=M,N  MCK=NC (N, KM)  MCK=NC (N, KM)  SUU CUN I INUE  NKN=K (N, NM)  NCN=K (N, KM)  IF (AHS (A (MKN, NCN, KM)), L1.1.E-10) WRITE (6, 6) 0100) KM, A (NKN, NCN, KM)  NCN=NC (N, KM)  IF (AHS (A (MKN, NCN, KM)), L1.1.E-10) WRITE (6, 6) 100) KM, A (NKN, NCN, KM)  SUU FURMAT(* LUSULV - RLOCK =*, 14, * LASI PIVUT IS*, E12.5)	A (HKL, NCM, KM) = A (NKL, NCM, NK) / HP 1 VO I  L= A (NKL, NCM, KM) = A (NKL, NCK, KM) - I * A (K I, NCK, KM)  DO 500 K=N, N  NCK=NC(N, KM)  NCN=I INUE  NNN=RK(N, NM)  NCN=NC(N, KM)  IF (AHS (A (MRN, NCN, KM) ) . LI · I · E - I 0) WRITE (6 · 6 I 00) KM, A (NKN, NCN, KM)  IF (AHS (A (MRN, NCN, KM) ) . LI · I · E - I 0) WRITE (6 · 6 I 00) KM, A (NKN, NCN, KM)  IF (AHS (A (MRN, NCN, KM) ) . LI · I · E - I 4, * PI VUI AI E UN NO. = * · I 2, * · E I 2 · 5)  6100 FUMMAT(* LUSOLV - BLOCK = * · I 4, * LASI PI VUI IS* · E I 2 · 5)
		A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1VU!  LEA (MKL, NCM, KM)  DG 500 K=M,N  MCK=NC (N, KM)  SUU A (MKL, NCK, KM) = 1 * A (K ( , NCN, KM))  SUU A (MKL, NCN, KM) = A (MKL, NCK, KM) = 1 * A (K ( , NCN, KM))  NNN=NC (N, KM)  NNN=NC (N, KM)  IF (AHS (A (MKN, NCN, KM)) * L1 * 1 * E = 10) * KM   E = 0N (NO = * * 12 * E)  SUUU FUMMAT(* LUSOLV - RLOCK = * * 14 * * E = 11 * E)  6100 FUMMAT(* LUSOLV - BLOCK = * * 14 * * E = 11 * E)	A (HKL, NCM, KM) = A (NKL, NCM, NK) / HP 1 VU I  LEA (NKL, NCM, KM) = A (NKL, NCK, KM) - I * A (KI * NCK, KM)  DUG 500 K=N, N  NCK=NC (N, KM)  DUG 500 K=N, NCK  NCK = NC (N, KM)  NCM = NC (N, KM)  IF (AHS (A (NKN) NCN * KM)) . LI * I * E = 10) WRI ! E (6 * 6 100) KM * A (NKN * NCN * KM)  IF (AHS (A (NKN) NCN * KM)) . LI * I * E = 14 * * E = 14 * * E = 12 * E =
L=a(nRL *NCM*KP)		A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1VU!  LEA(MKL, NCM, KM)  DU 500 K=M,N  NLK=NC(N, KM)  SUU A (MKL, NCK, KM) = A (MKL, NCK, KM) - I*A(KI, NCN, KM)  SUU A (MKL, NCK, KM) = A (MKL, NCK, KM) - I*A(KI, NCN, KM)  NLN=NC(N, KM)  IF (AHS(A (MKN, NCN, KM)) - LI·I·I·I·I·I·I) WRITE (6:6100) KM,A (NKN, NCN, KM)  IF (AHS(A (MKN, NCN, KM)) - LI·I·I·I·I·I·I·I·I·I·I·I·I·I·I·I·I·I·I·	A (HKL, NCM, KM) = A (NKL, NCM, NK) / HP 1 VU I  L= A (HKL, NCM, KM) = A (NKL, NCK, KM) - I * A (K I · NCA, KM)  DU 500 K=N, N  NCN=NC (N, KM)  NN=NC (N, KM)  IF (AHS (A (MRN, NCN, KM) ) - LI · I · E - I 0) WHITE (6, 6) 100 KM, A (NKN, NCN, KM)  NLN=NC (N, KM)  IF (AHS (A (MRN, NCN, KM) ) - LI · I · E - I 0) WHITE (6, 6) 100 KM, A (NKN, NCN, KM)  A RECK = * · I 4 · * PIVUI AI EUN NO. = * · I 2 · * · I 4 · *  6100 FURMAT (* LUSULV - BLOCK = * · I 4 · * LASI PIVUI IS* · EI 2 · S)
		A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1001  UG 500 K=M,N  MCK=NC(N, KM)  500 A(MKL, MCK, KM) = 1 * A (K   MCA, KM)  500 A(MKL, MCK, KM) = A (MKL, NCK, KM) = 1 * A (K   MCA, KM)  500 CON   INUE  NKN=K(N, KM)  NCN=K(N, KM)  I (AHS (A (MKN, NCN, KM)) . L1 · I · I · I · I · I · I · I · I · I ·	A (HKL, NCM, KM) = A (NKL, NCM, KM) / HP 1 VU I  L= A (NKL, NCM, KM) = A (NKL, NCK, KM) - I * A (K I, NCK, KM)  DU 500 K=H,N  FICK=NC(N, KM)  DU 600 CON I IMUE  NKN=K(N, NM)  NCN=NC (N, KM)  IF (AHS (A (MKN, NCN, KM)) - LI - I - I - I - I - I - I - I - I -
	L= (INKL.NCM.KA)  UG 500 K=M.N  NLK=NC(N.KM)  500 A(NHL.NCK.KM) = A(NHL.NCK.KM) - I*A(KI.NCN.KM)  500 A(NHL.NCK.KM) = A(NHL.NCK.KM) - I*A(KI.NCN.KM)  NNN=RK(N.NM)  NLN=RK(N.NM)  IF (AHS(A(MRN.NCN.KM)).LI.I.E-I0) WRITE(6.6100) KM.A(NHN.NCN.KM)  500 FUHMAI(* LUSOLV - RLOCK =*.14.* PIVUI AI EUN NO.=*.12.* IS*.EIC.5)  6100 FUHMAI(* LUSOLV - BLOCK =*.14.* LASI PIVUI IS*.EIC.5)	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1VUI LE A (MKL, NCM, KM) = A (MKL, NCK, KM) - I*A (KI, NCK, KM) DUG 500 K=M,N FICK=NC(N, KM) DUG A (MKL, MCK, KM) = A (MKL, NCK, KM) - I*A (KI, NCK, KM) DUG CON I I MUE NKN=KK(N, KM) IF (AHS (A (MKN, NCN, KM)), LI-1·E-10) WRITE (6·6100) KM, A (NKN, NCN, KM) IF (AHS (A (MKN, NCN, KM)), LI-1·E-10) WRITE (6·6100) KM, A (NKN, NCN, KM) ALOCK =*,14,* FIVUI AI EUN WO-=*,12,* IS*,EIZ-5) 6100 FUHMAT(* LUSOLV - BLOCK =*,14,* LASI PIVUI IS*,EIZ-5)	A (HKL, NCM, KM) = A (NKL, NCM, NK) / NP 1001  L=A (NKL, NCM, KM) = A (NKL, NCK, KM) - I * A (KI, NCK, KM)  DG 500 K=N,N  NCN=NC (N, KM)  NNN=NC (N, KM)  IF (AHS (A (MRN, NCN, KM)) - LI · I · E - I 0) WRITE (6 · 6 I 00) KM, A (NKN, NCN, KM)  SUU FURMAT (* LUSOLV - RLOCK = * · I 4 · * LASI PIVUT IS * · E I 2 · 5)  6100 FURMAT (* LUSOLV - BLOCK = * · I 4 · * LASI PIVUT IS * · E I 2 · 5)
Lea (nRL + NCM + NR)	L= 4 (NKL .NCM .KA)	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1VU!  LE A (MKL, NCM, KM)  UG 500 K=M,N  NCK=NC (N, KM)  SOU A (MKL, MCK, KM) = A (MKL, NCK, KM) = 1*A (K1.NCN, KM)  SOU A (MKL, MCK, KM) = A (MKL, NCK, KM) = 1*A (K1.NCN, KM)  NCN=NC (N, KM)  IF (AHS (A (MKN, NCN, KM) ) . L1 · 1 · E - 10) wKl ! E (6 · 6 100) KM, A (NKN, NCN, KM)  IF (AHS (A (MKN, NCN, KM) ) . L1 · 1 · E - 10) wKl ! E (0 · NO. = * · 12, * · 15 * · E 10. C)  A MAN I (* LUSOLV - RLOCK = * · 14, * * P   VU! A   E (N · NO. = * · 12, * · E 10. C)  A MAN I (* LUSOLV - RLOCK = * · 14, * * P   VU! A   E (N · NO. = * · 12, * · E 10. C)  A MAN I (* LUSOLV - RLOCK = * · 14, * · E 10. C)  A MAN I (* LUSOLV - RLOCK = * · 14, * · E 10. C)	A (MKL, NCM, KM) = A (NKL, NCM, NK) / MP1001  L=A (MKL, NCM, KM) = A (MKL, NCK, KM) - I * A (K I, NCM, KM)  DU 500 A (MKL, NCK, KM) = A (MKL, NCK, KM) - I * A (K I, NCM, KM)  DU CON I IMUE  NN = NK (N, NM)  NCN = NC (N, KM)  IF (AHS (A (MRN, NCN, KM) ) - LI · I · I · I · I · I · I · I · I · I
		A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1VU!  LE A (MKL, NCM, KM)  UG 500 K=M,N  MLK=NC (N, KM)  SUU A (MKL, MCK, KM) - I * A (K I, NCK, KM)  SUU CON I INUE  NKN=K(N, KM)  NKN=K(N, KM)  IF (AHS (A (MKN, NCN, KM)) - LI · I · E - 10) WRITE (6, 6100) KM, A (NKN, MCN, KM)  IF (AHS (A (MKN, NCN, KM)) - LI · I · E - 10) WRITE (6, 6100) KM, A (NKN, MCN, KM)  IF (AHS (A (MKN, NCN, KM)) - RLOCK = * · I 4, * PIVU! AI EUN NO. = * · I 2, * I 5 * · E I c · 5)	A (MKL, NCM, KM) = A (MKL, NCM, NK) / MP1001  L= A (MKL, NCM, KM)  DG 500 K=M,N  NCK=NC (N, KM)  DOU CON   IMUE  NKN=K(N, NM)  NCN=NC (N, KM)  If (AHS (A (MKN, NCN, KM)) - L1 - L - L0) WRITE (6, D100) KM, A (NKN, NCN, KM)  If (AHS (A (MKN, NCN, KM)) - L1 - L1 - L1 + P1001 A1 E ON NO.=#+12, # 15#, E12.5)
	LEALURI . N.C. N.	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1VUI LE A (MKL, NCM, KM) = A (MKL, NCK, KM) - I * A (KI, NCK, KM) DU G SUU KINCK, KM) = A (MKL, NCK, KM) - I * A (KI, NCK, KM) DUU CON I IMUE NAN=RK (N, KM) NCN=NC (N, KM) IF (AHS (A (MKN, NCN, KM)), LI-1·E-10) WRITE (6+6100) KM, A (NKN, NCN, KM) A (MKN, MK) IF (AHS (A (MKN, NCN, KM)), LI-1·E-10) WRITE (6+6100) KM, A (NKN, NCN, KM) A (MKN, MK) IF (AHS (A (MKN, MKN, MKN, MKN, MKN, MKN, MKN, MKN,	A (HKL, NCM, KM) = A (NKL, NCM, NK) / NP 1001  LEA (NKL, NCM, KM) = A (NKL, NCK, KM) - I * A (KI, NCK, KM)  DU SOU A (NHL, NCK, KM) = A (NKL, NCK, KM) - I * A (KI, NCK, KM)  DOU CON I INUE  NKN=K(N, KM)  IF (AHS (A (MKN, NCN, KM)) - LI · I · I · I · I · I · I · I · I · I
Lea (MML + NCM + NF)	L= 4 (NKL .NCM .KB)	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1 VOI LE A (MKL, NCM, KM)  UG 500 K=M, N  NCK=NC (N, KM)  SOU A (MKL, NCK, KM) = A (MKL, NCK, KM) - I * A (KI, NCN, KM)  SOU CON I INUE  NKN=K (N, KM)  NCN=NC (N, KM)  IF (AHS (A (MKN, NCN, KM)) - LI · I · I · I · I · I · I · I · I · I	A (MKL, NCM, KM) = A (NKL, NCM, NK) / MP 1 VO I  L=A (NKL, NCM, KM) = A (NKL, NCK, KM) - I * A (K I, NCN, KM)  DU 500 A (NKL, NCK, KM) = A (NKL, NCK, KM) - I * A (K I, NCN, KM)  DU CON I IMUE  NNM=RK (N, NM)  NCN=RC (N, KM)  IF (AHS (A (MRN, NCN, KM)) - LI · I · I · I · I · I · I · I · I · I
	1= 4 (NRL *NCM*KA) UG 500 K=H*N NCK*KM) = A (NRL *NCK*KM) - 1 *A (K   *NCK*KM)  500 A (NRL *NCK*KM) = A (NRL *NCK*KM) - 1 *A (K   *NCK*KM)  600 CON   INUE NKN=K(N*M) NCN=NC(N*KM) 1F (AHS (A (MRN*NCN*KM)) - LI - I - E - I 0) wRI   E (6*6100) KM*A (NRN*MCN*KM)	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1401  UG 500 K=M,N  MCK=NC(N, KM)  SUU A(MKL, MCK, KM) = A (MKL, NCK, KM) - I * A (K I, NCN, KM)  SUU CON I INUE  NKN=K(N, KM)  IF (AHS (A (MKN, NCN, KM)) - LI - I - E - I 0) WRITE (6, 6) 100) KM, A (NKN, MCN, KM)	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP 1 VU I  1= A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP 1 VU I  500 A (MKL, MCK, KM) = A (MKL, NCK, KM) - I * A (K I · NCM, KM)  600 CON I IN UE  NEN = LM (N, NM)  NCM = NC (N, KM)  1 (AHS (A (MKN, NCM, KM)) - LI · I · E - I 0) WHI ! E (6 · 6 I 00) KM, A (NKN, MCN, KM)
L=	LE GINKL .NCM.KA)  UG 500 K=N.N  NLK=NC(N.KM)  500 A(NHL.NCK.KM) = A(NHL.NCK.KM) - I*A(KI.NCN.KM)  600 CON INUE  NKN=K(N.KM)  NCN=NC(N.KM)  IF (AHS(A(MRN.NCN.KM)).LI.1.E-10) WRITE(6:6100) KM.A(NKN.NCN.KM)	A (MKL, NCM, KM) = A (MKL, NCM, KM) / MP1 VUI LE SUB K=M, N FICK = NC (K, KM) FICK = NC (K, KM) 500 A (MKL, MCK, KM) = A (MKL, NCK, KM) - 1*A (K (, NCK, KM)) 500 CON I IMUE NKN=K (N, KM) NCN=NC (N, KM) IF (AHS (A (MKN, NCN, KM)), LI-1·E-10) WRITE (6+6100) KM, A (NKN, NCN, KM)	A (HKL, NCM, KM) = A (NKL, NCM, NF) / HP 1 VO I  LEA (INKL + NCM + KM)  UG 500 K= H, N  NCK = NC (N + KM)  SUU A (NKL + NCK + KM) = A (NKL + NCK + KM) - I * A (K I + NCK + KM)  SUU CUN I INUE  NKN= K (N + KM)  NCN = NC (N + KM)  IF (AHS (A (HRN + NCN + KM)) - LI - I - E - I 0) WRITE (6 + 6 I 00) KM + A (NKN + NCN + KM)
Lea (WRL + NCM + KM)	L=a (WRL *NCM*KA)	A (MML, NCM, KM) = A (MML, MCM, KF) / MP 1 VOI LEA (MML, NCM, KM) = A (MML, MCK, KM) = 1*A (K 1. NCK, KM) 000091 DOU CON I INUE NCM, KM) = A (MML, NCK, KM) = 1*A (K 1. NCK, KM) 000091 DOU CON I INUE NCM, MM) 000092 NCM=NC (N, KM) 000092 It (AMS (A (MMN, NCM, KM)) 11.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.	A (MML, NCM, KM) = A (MML, NCM, KM) / MP 1 VU I  1 = A (MML, NCM, KM) = A (MML, NCM, KM) / MP 1 VU I  100 500 K=M, N  100 500 K=M, N  100 500 K=M, N  100 A (MML, NCK, KM) = A (MML, NCK, KM) - I * A (K I, NCK, KM)  100 CON   INUE  11 NN = NK (M, NM)  12 (AMS (M, KM)  13 (AMS (M, KM)  14 (AMS (M, KM)  15 (AMS (M, KM)  16 (AMS (M, KM)  17 (AMS (M, KM)  18 (AMS (M, KM)  18 (AMS (M, KM)  19 (AMS (M, KM)  19 (AMS (M, KM)  10 (M, MS (M, KM)  10 (M, MS (M, KM)  10 (M, MS (M, KM)  11 (AMS (M, KM)  11 (AMS (M, KM)  11 (AMS (M, KM)  12 (M, KM)  13 (M, KM)  14 (AMS (M, KM)  15 (M, KM)  16 (M, KM)  17 (M, KM)  18 (M, KM)  19 (M, KM)  1
1=a (WRL + NCM + KR) UG	L=a (wkl . ncm . kh)	A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP 1 VOI 1= A (WKL, NCM, KM) = A (WKL, NCM, KM) - I * A (KI, NCK, KM) 500 A (WKL, NCK, KM) = A (WKL, NCK, KM) - I * A (KI, NCK, KM) 000091 000091 000091 000091 000092	A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VU I  1= A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VU I  10
L= a (wkl + NCM+kh)	L=A (WRL *NCM *KA)	A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VO	A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP 1 VOI L=A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP 1 VOI UG 500 K=M,N RICK=NC (K, KM) RICK=NC (K, KM) = A (WKL, NCK, KM) - I * A (K I, NCK, KM) 000091 NCN=NC (W, KM) NCN=NC (W, KM)
Lea (WRL + NCM + KP)	L=a (wkl + NCM + KA)	A (MKL, NCM, KM) = A (MKL, MCM, KM) / MP1V01  1=A (MKL, NCM, KM)  100 500 K=M,N  100 500 K=M,N  100 500 K=M,N  100 00091  100 A (MKL, MCK, KM) = A (MKL, NCK, KM) - 1*A (K1, NCK, KM)  100 00091  100091  100091  100091  100091  100091  100091  100091  100091	A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VO I  1 = A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VO I  10 500 K = M, N  10 500 M = M, N  10 1 M = M  10 1 M = M, N  10
Lateral   Local   Lateral   Local   Lateral   Local		A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VOI 1= A (MML, NCM, KM) = A (MML, MCM, KM) - I * A (KI, MCK, KM) 000091 000091 500 A (MML, MCK, KM) = A (MML, MCK, KM) - I * A (KI, MCK, KM) 000091 000091 000091 000091	A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VU I  1= A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VU I  100 500 N=M, N  100 500 N=M, N  100 000 A (MML, MCK, KM) = A (MML, MCK, KM) - 1 * A (K I, MCK, KM)  100 000 CON I I MUE  100 000 CON I I MUE  100 000 WM I MUE  100
Lateral   Lateral	L=A (WRL *NCM*KA)	A (MML, NCM, KM) = A (MML, MCM, KM) / MP1001  1= A (MML, NCM, KM)  106 500 K=M, N  107 500 K=M, N  108 500 K=M, NCK, KM)  108 500 A (MML, NCK, KM) = A (MML, NCK, KM) = 1*A (K 1. NCK, KM)  108 600 CON I IN (KM)  108 600 CON I IN (KM)  108 600 CON I IN (KM)  108 600 CON (KM)	A (WKL, NCM, KM) = A (WKL, NCM, NF) / MP 1 VOI 1= A (WKL, NCM, NR)   000091 UG 500 N=M,N NCN=NC(N, NM)   000091 500 A (WKL, NCN, KM) = A (NKL, NCN, KM)   1#A (KI, NCN, KM)   000091 000091 000091
Lea (WRL - NCM - KP)	L=a (wrl . ncm . kg)	A (MKL, NCM, KM) = A (MKL, MCM, KM) / MP1V01  1=A (MKL, NCM, KM)  100 500 K=M,N  100 500 K=M,N  100 500 K=M,N  100 00091  500 A (MKL, MCK, KM) = A (MKL, NCK, KM) - 1*A (K1, NCK, KM)  100091  100091  100091  100091	A (MML, NCM, KM) = A (MML, NCM, KM) / MP 1 VOI 1= A (MML, NCM, KM) = A (MML, NCM, KM) - I*A (KI, NCM, KM)  500 A (MML, MCK, KM) = A (MML, NCK, KM) - I*A (KI, NCM, KM)  600 CON I INUE  WANTERNAMENTAL
Lateral   Lateral   Local   Lateral   Local	1=a (wkl . wcm.kfl)  UG 500 n=m.n  NCN=NC (N.*NM)  500 A (wklwcn.km) = A (wklwck.km) - 1*A (K1.NCN.km)  000091  000091	A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VOI 1 = A (MML, NCM, KM)   000091 10 500 K = M, N 11 CK = NC (K, KM)   000091 500 A (MML, MCK, KM) = A (MML, NCK, KM) - 1 * A (K I, NCK, KM)   000091 000091	A (MKL, NCM, KM) = A (MKL, NCM, KF) / MP 1 V U I U U U U U U U U U U U U U U U U U
Later   Late	L=A (WRL + NCM + KA)	A (MML, NCM, KM) = A (MML, MCM, KM) / MP1001  L=A (MML, NCM, KM)  UG 500 K=M,N  MCK=NC (K, KM)  500 A (MML, NCK, KM) = A (MML, NCK, KM) - 1*A (K1, NCK, KM)  000091  000091  000091	A (MML, NCM, KM) = A (MML, NCM, NF) / MP 1 VU I  1=A (MML, NCM, KM) = A (MML, NCM, NF) / MP 1 VU I  100 500 N=M,N  11CN = NC (N, NM)  500 A (MML, MCK, KM) = A (MML, NCK, KM) - I*A (K I, NCK, KM)  0000091  0000091
LEA (WRL + NCM + KP)	L=a (wrl . ncm . kr)	A (MKL, NCM, KM) = A (MKL, MCM, KF) / MF1VUI  1=A (MKL, NCM, KM)  100 500 K=M,N  100 500 K=M,N  11CK=NC(K, KM)  500 A (MKL, NCK, KM) = A (MKL, NCK, KM) - 1 # A (K 1, NCK, KM)  1000091  1000091	A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VOI   000091   1= A (MML, NCM, KM)   000091   0000091   000091   000091   000091   000091   000091   000091   000
Lateral   Local   Lateral   Local   Lateral   Local	LEA (WRL .NCM.KR)  UG 500 N=M.N  NCN=NC (N.NM)  500 A (WRL.NCN.KM) = A (NRL.NCN.KM) — 1 # A (K 1.NCN.KM)  000091	A (MML, NCM, KM) = A (MML, MCM, KM) / MP1VUI  1= A (MML, NCM, KM)  100 500 K=M,N  11CK = NC(K, KM)  500 A (MML, MCK, KM) = A (MML, NCK, KM) - 1*A (KI, NCK, KM)  000091	A (MKL, NCM, KM) = A (MKL, NCM, KF) / MP 1 VOI 1= A (MKL, NCM, KF) UG 500 N=M,N NCN = NC (N, KM) 500 A (MKL, NCN, KM) = A (MKL, NCN, KM) — I # A (K I, NCN, KM) 000091
	L=A (WKL + NCM + KA)	A (MML, NCM, KM) = A (MML, MCM, KF) / MP1VUI  L=A (MML, NCM, KR)  UG 500 K=M,N  NCK=NC (K, KM)  S00 A (MML, NCK, KM) = A (MML, NCK, KM) - 1*A (K1, NCK, KM)  000091	A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP 1 VU I  1= A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP 1 VU I  100 500 K=M,N  100 500 K=M,N  100 500 K=M,N  100 A (WKL, NCK, KM) = A (MKL, NCK, KM) - I * A (K I, NCK, KM)  100 00091
Lateral   Local   Lateral		A (MRL, NCM, KM) = A (MRL, MCM, KF) / MP1001  L=A (MRL, NCM, KF)  UG 500 R=M,N  NCR=NC(N, KM)  S00 A (MRL, MCK, KM) = A (MRL, NCK, KM) - 1*A (K 1. NCK, KM)  000091	A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VU I  1= A (MML, NCM, KM) = A (MML, MCM, KM) - I*A (KI, MCK, KM)  500 A (MML, MCK, KM) = A (MML, NCK, KM) - I*A (KI, MCK, KM)
1=4 (WRL + NCM + KP)  UG 500 K=11,N  NCK=NC (K+KM)  500 A (WRL+MCK+KM) = A (NKL+NCK+KM) - L*A (K I+NCK+KM)	1=4 (WKL . NCM . KM)  UG 500 K=M.N  NCK=NC (K. 1 . NCK . KM) = A (NKL . NCK . KM) - I # A (K I . NCK . KM)	A (MML, NCM, KM) = A (MML, MCM, KM) / MP 1 VOI 1= A (MML, NCM, KM) UG 500 K=M,N NCK=NC(K, KM) = A (MML, NCK, KM) - I * A (KI, NCK, KM) 000091	A (MKL, NCM, KM) = A (MKL, NCM, KF) / MP 1 VO 1  1= 4 (MKL, NCM, KF)  10 500 N=M,N  10 500 N=M,N  11 CN = NC (N, NM)  12 (MKL, MCN, KM) = A (MKL, NCK, KM) - 1 # A (K 1, NCN, KM)
	1=4 (WKL .NCM .KM)  UG 500 K=M.N  UG 500 K=M.N  UC 500 K=M.N  UU00091  UU00091  UU00091  UU00091  UU00091  UU00091	A (MML, NCM, KM) = A (MML, MCM, KF) / MP1VUI  L=A (MML, NCM, KR)  UG 500 K=M,N  MCK=NC (K, KM)  500 A (MML, NCK, KM) = A (MML, NCK, KM) - 1*A (K1, NCK, KM)	A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP 1 VU I  1= A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP 1 VU I  100 500 K=M,N  100 600 F=M,N  100 600 F=M,N  100 600 F=M,N  100 600 F=M,N  100 7 F=M,N  100
L=	L= A (WRL + NCM+KP)	A (WRL, NCM, KM) = A (WRL, NCM, KM) / MP 1 VU I  L=A (WRL, NCM, KM) = A (WRL, NCM, KM) = 000091  UG 500 R=M, N  NCR=NC (R, RM)  A (WRL, NCR, KM) = A (WRL, NCR, KM) - I # A (KI, NCR, KM)	A (WKL, NCM, KM) = A (WKL, NCM, KF) / NP 1 VU 1  L= A (WKL, NCM, KR)  UG 500 K=11, N  NCK=NC(N, KM)  A (WKL, NCK, KM) = A (WKL, NCK, KM) - 18A (KI, NCK, KM)
L=a(nMt.NCM.KA)	L= A (NHL + NCK + KM) = A (NKL + NCK + KM) = L + A (K   + NCK + KM)	00009] A (WKL,NCM,KM) = A (WKL,NCM,KM) / MP1v01 L=A (WKL,NCM,KM) UG 500 K=M,N NCK=NC(K,KM) A (WKL,NCK,KM) = A (MKL,NCK,KM) - L*A (K,KM) - L*A (K,KM)	A (WRL, NCM, KM) = A (WRL, NCM, KM) / MP 1 v U I  L= A (WRL, NCM, KM) = A (WRL, NCM, KM) - I & A (KI, NCM, KM)  A (WRL, NCK, KM) = A (WR, NCK, KM) - I & A (KI, NCM, KM)
L=A (INRL + NCM+KP)		A (WRL, NCM, KM) = A (WRL, NCM, KM) / MP1 vol L=A (WRL, NCM, KM) UG 500 K=M,N NCK=NC(K, KM) 000091	A (WKL, NCM, KM) = A (WKL, NCM, KM) / MP 1 VOI 1= A (WKL, NCM, KM) UG 500 K= M, N NCK = NC (K, KM) 000091
000091 500 K=11.N (=NC(N.RM)	000091 500 N=11.N 500 N=11.N	00009] INKL,NCM,KM) = A (NKL,NCM,KM) / NP1v01 00009] 500 N=M,N	00009] (INKL *NCM *KM) = A (NKL *NCM * KF) / NF 1 VU   00009] 500 N=11 *N 500 N=11 *N 00009]
00009] 500 N=11.N 00004]	(NML +NCM-NF)	000091 (INKL *NCM*KF) 500 K=M*N 500 K=M*N	INL, NCM, KM) = A (NKL, NCM, KM) / NP1v01 (INKL, NCM, KM) = A (NKL, NCM, KM) / NP1v01 000091 500
00009] 500 N=M.N 00009]	1 (NML + NCM + KF)	000091 (INKL *NCM *KF) = A (NKL *NCM * KF) / NF1 vOI 000091 500 N=11,N	INL, NCM, KM) = A (NHL, NCM, KM) / NPIVUI (INKL, NCM, KM) 500 K=M, N = NCM, KM)
000091 500 K=H+N	SOU N=H-N OUDUS]	000091 000091 500 N=M+N	OUOU91 SOU KEYNCM.KM) = A (NML, NCM, KF) / NF 1 VUI OUUU91 SOU K=M.N SOU K=M.N
000091 500 K=11.N	000091 500 N=11.N	OUUU9] INL, NCM, KM) = A (NKL, NCM, KM) / NPIVUI I (NKL, NCM, KM) SUU N=M, N UUUU9]	OUUU9] I (INKL * NCM * KM) = A (NKL * NCM * KM) / NF 1 VU I UUUU9] 500 N=11.N
000091 500 N=11.N	1 (NML + NCM + KF) 500 N=11.N	DODOUGH KM) = A (MML, MCM, MF) / MPIVUI (INKL, NCM, KF) (MML, NCM, KF) (MML, NCM, KF) (MML, NCM, MF) (MML, NCM, NF) (MML, NCM, NCM, NCM, NCM, NCM, NCM, NCM, NCM	OUDDY OF THE NEW, THE NEW, THE COUDDY OUDDY OUDD
000091 500 K=1.N	(NML + NCM + NF)	OCCOUPT  LINKL *NCM * KM) = A (NKL *NCM * KF) / NFI VOI  COUCUST  SOU R=11 *N	INCH, NCM, KM) = A (NHL, NCM, KM) / NPIVUI (INKL, NCM, KM) (INKL, NCM, KM) 500 N=M, N
COCCOT	CONTRACTOR A PRINCE OF THE PRI	OCCOUPT	INCH, NCM, KM) = A (NKL, NCM, KF) / NP LVUI  UUUU9]
UUUU91	(LINE - NCM - KFI)	OUDDOS ONCH, KM) = A (MKL, MCM, KM) / MPIVUI (MKL, MCM, KM) = A (MKL, MCM, KM) / MPIVUI (MKL, MCM, KM) = A (MKL, MCM, KM) / MPIVUI (MKL, MCM, KM) = A (MKL, MCM, KM) / MPIVUI (MKL, MCM, KM) = A (MKL, MCM, KM) / MPIVUI (MKL, MCM, KM) = A (MKL, MCM, KM) / MPIVUI (MKL, MCM, KM) = A (MKL, MCM, KM) / MPIVUI (MKL, MCM, MCM, MCM, MCM, MCM, MCM) / MPIVUI (MKL, MCM, MCM, MCM, MCM, MCM, MCM, MCM, MC	OUDDOST OF THE SUCH SUCH SUCH SUCH SUCH SUCH SUCH SUCH
LINKL +NCM+KFI)	(INKL + NCM + KF)	ODDOY!	INT. NCM, KM) = A (NKL, NCM, KM) / NP 1 VUI
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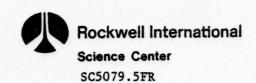


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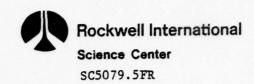
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		0010100
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(A/ A(4,4,1)	to((4.1)	00010580
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C'SULVE Y IN L # Y = F		00010320
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00 300 L=1.N		00010340
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DO +00 K=L1+W		00010200
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CONTRACTOR OF THE PROPERTY OF		

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REARRANGE COMPONIENTS DUE 10 MINEU PIVOFING  DO 600 L=1.N  NCL=NC(L.M)  KEIUKN  END  SUBDONIENCE	IS FUM LUG. SPRIAL. SHOULD BE CHANGED FUR UIMER CURVED WALLS CUMMUN /pARM2/ plip2:p3:p4:p5:p6 CUMMUN /pARM5/ KOUNI,xN,nK,X CUMMON /PARM6/ KOUNI,xN,nK,X CUMMON /CONSI/ C1:C2:C3:C+:C5:C6:C/ P1=0. P2=C1/(X+1.2*C1) P3=4.*P2*X**0.75*C2 P4=0. P5=C1/(X+1.2*C1)	HAMADALIAN INUMULENCE MODEL ( REFERENCE RAPADALIAN - TURBULENI WALL- DIFFUSENS, ALAA VOL. 11, NO. 12, PP. LOH4_LOYU, 1973 )  CUMMON /WI/ WI(2.1) /UL/ U(4.1) /G/ U(4.1) /MESHY/ H(1)  CUMMON /PARMA/ PI.PZ.P3,P4,P5,P6  CUMMON /PARMA/ NU.NW.J  CUMMON /PARMA/ NU.NW.J  CUMMON /PARMA/ NU.NW.J  CUMMON /PARMA/ NU.NW.J  CUMMON /PARMA/ FACX:HKS:AA:XH:YA:YA:YA:AA  CUMMON /PARMA/ FACX:HKS:AA:XH:YA:YA  CUMMON /PARMA/ FACX:HKS:AA:XH:YA:YA  CUMMON /PARMA/ IFLAG:YIC.YICLD-YICLD-YICLD-YICLD-YICLD-YICLD-NE-YIC)  IF (ITEAG.EO.1) GO TO 400  IF ((TIC-YICLD) GO TO 90  YICLAMAXI(YIC:YICLD)  SO TO 400  90 CCMIMOLE  YICLD-YIC  YICLD-YIC  YICLD-YIC	1-7-10

2000



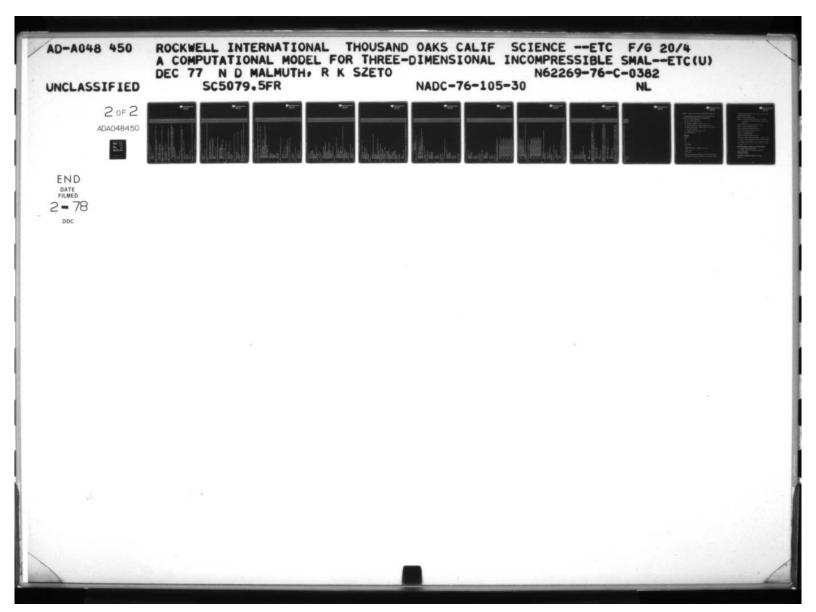
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																				WOON THE CO							OM THE PREIVOUS SIREAMWISE HERE IL IS SOLUTION OF			13											And I was I've sale in a
CINCIO MILLO DE LA COLLA DEL COLLA DE LA COLLA DEL COLLA DE LA COLLA DEL COLLA			##5+W	00 10 100									O(3+L) **Z+w  (Z+L) **Z)				##0.55 (0.435 47) ##2#UNUym			WYDNIA2**(LX*5/21*0)*5/2*0**X+*[=(]*2)9							MOMPHICAL FORESTION FROM	A AI THE PHEVIOUS SI		mr(1) /UIX/ U(4.1) /6/ G(4.1)	UN(4) + UHX (4) +FF (+) + AJA (4++)	FI.PZ.PJ.F4.F5.P5	7.82.62	FACKORRS PAGGES TAGGES	VIOLEN STATES						A District of the Control of the Con
C 00 100 LL=1,J1		( ) H= 1 = 1	UPDRM=SURT (UCZ,L)	IF LUNDAM . L. L. O. O. D.	Ten Centralia				400 CUNTINUE		Y=0.	Un 300 L=1.J	UNURMESURI (U(3.L)	Flasi LAYED			012,1,1=1.+X**U.25		SECUMI LAYER	IF (Y. 6t. Y (C) 6(2)		300 CONTINUE	, to 100 m	KE LOKE	SUBROULINE PREPG		INTS SUPPOULT F COMPUTES T	VELOCITY		/ME SHI/	/SF [UP/	/PAKAZ/	/PARM4/	/ Paridy	CONTROL SPARMOS NO	Ut.COU=0.		L=2.			Control of the state of the sta

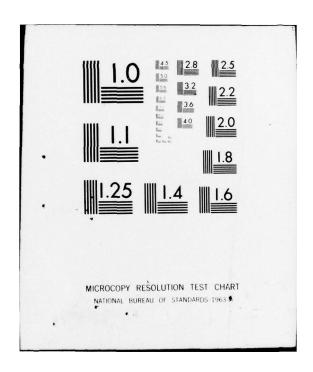


00011670	00011680	00011700	00011720	00011732	00011740	00011750	00011760	00011780	00011790	00011800	00011820	00011830	00011850	00011860	00011870	00011880	00011900	01611000	00011920	00011930	00011950	00011960	07611000	06611000	00015000	00012010	00012030	00012040	00017000	00012060	00012070	05021000	00012100	00012110	00012120	00012140
	10 UH(K) = (U(K,L) +U(K,L-1))/2.	C CUMPULE CONTRIBUTION	9	1 +HY(L-1)*(UH(1)*UH(3)*(1.+P1-4.*Pb)+2.*UH(2)**2*(1.+2.*Pb) 2 +4.*A**. (5*UH(4)*(H.*Pb+1.)*DE(50)	2		C 100 CONTINOE		SUBBOILT INE MC	an July Course		C THE BOUNDARY CONDITIONS FOR THE STREAMASTE MOMENTOM EQUATION C FUNCTION STATEMENT FN(X) HAS TO BE THEST BY USER FOR HIS OWN CO-	FLUWING HOUNDARY CONDITION AT INFINITY	Chambre	(LIMMAIN / CANST / C1 / C2 / C4		CUMMON / PARME		יייי אירי אף יייי		0(2)=UA(2)	G(4)=[JB(4)	0 (1+1)=1.	U(4,4)=1.		A STANDARD AND AND A STANDARD AND AND AND AND AND AND AND AND AND AN		9(3)=yd(1)+2,*yd(2)/C3+yd(3)/C3**2-C3	H(3,2)=2,/C3	H(3,3)=1./C3##2	5 (3.1) = 1.	100 CONTINUE		C BUUNDARY COMPTION FOR S GREATER THAN ZERU		4 (3+2) = 1.

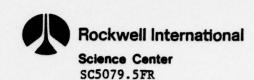


Common   Parker	00012100	00012170	00012180	00012190	00012200	00012210	00012220	00012240	00012250	00015560	00612270	00012280	00012290	00015300	00012302	00012320	00012330	00012340	00012350	06012360	00012380	00012390	00012400	00012410	00012420	0012440	00012450	00012460	00012470	00012480	06421000	00021000	00012520	00012530	00012540	00012550	E00012570	00012580	06521000	00012600	00012610	00012620	00012630	01012640
		EM)	SUBRECULTINE REISE		1415 SUMROUTTAL COMPUTES THE KIGHT HAMD STUE OF THE		CUMMON /SF TUE/	/PHHHA/	CUMMON PARMO		DLCdμ=0.	F(1 =U(2)		(Id[) -= (E) 4	* (<) 0 * 2 d = (+) 4		AL IUAN		SUHROUIINE	THIS SUBMOULINE COMPUTES THE JACONIAN MAIRIX OF THE	MUMENIUM EQUALTON	ن	CUMMON /St TUP/	/PAKMZ/	COMMON /PARING/		A(1,2)=1.		A(3.1) =-(1.+P1) #U(3)-4.#P6#(U(3)+UA(31)	A(3.2)=4.*((2)*(-1.+2.*Pb)	A(3,3) = (   •+P1) *(I(1) +4•*P*(U(1) +I)A(1))	A (4.2) = 2.4000 = 1.0	. 7 dx • 7 - 17 t + 1 V	Mt I UMN		SURKOULINE	THIS SUBDOUTER COMMUNES THE COMMUNITION FROM THE COEVIDING	STATION OF THE SPANWISE MOMENTUM FOUNTION		12WHV1/	/FIKM4/	/FARMS/ FACX+HES+AA+AB+YA+YA+NA	/WI/ WI(2*1) /WIX/ WIX(2*1) /UI/	767 5 (4 1 1 7ME SHY)

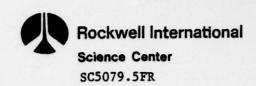




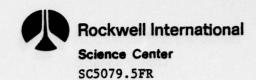
00012660 00012670 00012680 00012690	00012720 00012720 00012730 00012740 00012750 00012760	00012800 00012810 00012810 00012830 00012830 00012850 00012850	00012896 00012896 00012900 00012900 00012900 00012960 00012960 00012960 00012960 00012960 00012960 00013060 00013060 00013060
C Y=YA+HY(1)/2. bc 100 L=2.J L1=L-1	MINWAY HEIWEEN INO VERLICAL NET POINTS FOR THE DUS STREAMWISE STATIONS LI)+UTX(R,L))/2. LI)+UT(R,L))/2.	C DEJAIN W AT POINT C PREVIOUS STREAMWISC C DO 20 N=1.NW 20 UN(K)=(WIX(K,L CALL PREPP(Y) C COMPUTE CONTRIBUTE C SPANWISE MOMENTUM C SFANWISE MOMENTUM C 6(3,L)=6(1,L)*	1 L1) **(IL,*PI) **(IL,*PI) **(VH(I) **(VH(I) +*, **P6**  2 (UH(I)*(VH(2)**(YHX(2))**(UH(I) **(VH(I))**) **SQRT(X)**P5**  3 (VH(2)**2*VHX(2)***P3)  Y=Y*(HY(L))**(IL) **(YHX(2))**(IL) **P6**  100 CONI INUE  KEIUAN  CHELUAN  CHIS SURMOUTINE HC**  C UNMON /SFTUP/ UA(4)**UB(4)**G(+)**H(4***)  UO 10 L=1*2  C HSI SUBHOUTINE COMPUTES THE HIOTI HARIE SIDE UF THE SPANWISE MORENTUM ENU  C UMMON /S*TUP/ V(4)**VX(4)**F(4)**  C HSI SUBHOUTINE COMPUTES THE HIOTI HARIE SIDE UF THE SPANWISE MORENTUM ENU  C COMMON /S*TUP/ V(4)**VX(4)**F(4)**  C COMMON /S*TUP/ V(4)**VX(4)**F(4)**



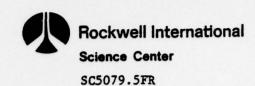
1	00013140	00013150	00013160	00013170	CKUSS-FLUM 00013190	00013200	00013210	00013220	00013230	00613240	04681300	00013260	 00013280	00013290	00013300	_	00013320		00013350	00013360	00013370	00001000	00013400	00013410	00013420	05451000	0.0013450	00013460	00013470	00013480	16451000 1651-4000	00013310	00013520	00013530	00013540	00013550	00013560	00013580		1000	00013600	
	.01	AT LOXN		SURROUTINE JACOHW	IMIS SUBMULIINE COMPULES THE JACUSTAN MAINTY FUR THE SMALL	No.		CUMMON / LARME/ LINDS 13 17 1 15 15 10	.>		1 /4 * d # .	A (7.07) = - (1.47) \$ (1) - 4.45 \$ (2) - 2.0 ( )	END	SUBMOUTINE OUTPI (J, YA)		IMIS SUMMOUTINE WRITES THE SOLUTION ON PAPER	Liberton Cacha Cacha	COMADN /WI/ WI(20151)	SEUIC	COMMON /UT/ UI(4.151) /MESAT/ H(151)	TELEGRAPH OF TO JOS		PHINI SIREAMMISE VELUCITY VECTUR ONLY		** [FE (6+6100)	-	•	110 CUNITNUE	KE TURN	And a Manager	PRIMI HOLD STREMMISE AND SPANMISE VELICITY VELICITY	200 WHITE (6+0300)	U0 390 L=1.J	WK1 (E (6.0400) L,Y, (UT (K,L),K=1,4), (" (K,L),K=1,2)		300 CONTINUE	1/6. 6. 4. 4. 4. 4. 4. 4. 4. 4. 4. 4. 4. 4. 4.	FUKMA   (14.5/14.E	FURMATIV/10X+#Y#	(//amn+ 1	6400 FUMMAI(14.7(114.E14.1))	



SURKOUTINE NETRUM	00013640
NET SELECTION - APPROXIMATELY CHOOSING MIN WITH THE INUNCATION ERROR	00013660
	00013680
CUMMON /US/ US(4+1) /UI/ US(4+1) /ANEW/ HNEW(1) /MESHY/ H(1)	00013690
CUMMUN INET JMAX, HMAX, ITMX, RSAME	00013710
/FARM4/	00013720
-	00013730
VIEL IV	00013740
DIMESSION 2 (2000) • KI(10)	0013750
LOGICAL DELI-UEL2	00013770
	00013780
KS INGK=1	00013790
NSING(1)=J	00013800
NE I INC = 0	00013870
AKLA=0.	00013830
KSAME = U	00013840
I+WX=1	00013850
1-f=1r	00013860
Nº 1-9 Nº 1-9 N	00013870
SUM (K) = 0.	00013680
	00651000
C COMPUTE LOCAL INUNCALION FRAUM AL MIU-PUTAL	01651000
	06013920
KTYPt =-1	00013930
00 360 L=1,J	00013940
14 (L. t.u. 1) 60 f0 100	00013960
	00013970
05 01	00013980
THE STATE OF THE PROPERTY OF T	0601000
C PUINT MEFORE SINGULARITY OR KINDIN FRU-PUINT	010+1000
,	00014020
KIYPt=1	02014030
ON THE PART OF THE	04011000
	00014000
C pulni at ten Sintolentily	00014010
	00214080
K   Y   F   -	00011000
	0014100
	00014120
Unite) = (Ulitati) + Ulitati))/2.	00014130
100	00014090 00014100 00014110 00014120



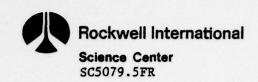
	CALL INON	NO	7	
	•		00014100	
	DO 200 R	Z I I	00014170	
	F(Kel)=Lailo(K)	(X)	08141000	
	1=141		00111000	
		2-1412	06141000	
	200 CONTINUE		00014200	
	(1) INDS=		00014210	
	Z(L)=1		00014220	
	AKEA=AFE	AFF 3 = 4 FF 4 = 1 + 4 FF 7	00014230	
	300 CON 1 14UF		01014240	
٠,			00014250	
,	CUNS FC=AJFA/JE	A.F. A. J.	00014260	
			00014270	
, 0	NET SELECTION	Or and Principles of the Control of	00014280	
			00014500	
,	LA=1		00014300	
	UU 2000	UU 2000 KUUI=1.KSINGK	00014310	
	LHEKSIN	L## 5   NG (* 002) - 1	00014320	
	IF (KOU) colors	(i. i.) I A=KCING(KOUI)	04614330	
	DELI=FALSF.			
	(1) 1 3 - 1 V   SE		0.0014360	
	חור זייטיי		05541000	
	0001 00			
	TACIENT.	ACI=H(L) **2*2 (L) / (Z**CON3) (C)	00014370	
	FACT=SU	FACT=SURI (FACT)		
	2 (L) = F ACT		00014390	
	KJS=FACI+11.5		*	
	IF (KJS.LE.1)	LE.1) 50 10 700	4	
ပ			00014420	
	AUDITION		00014430	
ပ			00014440	*
	IF ((L+K.	1F((L+KJ5+NETINC+1).6T.JMAX) 60 10 2500	00014450	
	NSAME = 1		00014400	
	IF MX=MA	IFMX=MAXU(IFMX,KJS)	00014470	
	HI=H(1)/KJS	/k.JS	00014480	
	UU 600 M=1.KJS	M=1,KJS	00014490	
	HNE M INE	HNE # (NE ] INC+M-1+L) =H!	00014500	
	No 000 N=1.N	N. I = X	00014510	
	USIKINE	US(K.NE] ISC+M-1+L)=((M-1)+C (K.L+1)+(RUS-(M-1))+UI(K.L))/KUS	00014520	
	600 CUNTINUE		00014530	
	NE I INC =	NE I INC = WE I INC + RUS-1	4	
	DELI= . FALSE .	AL SÉ.	00014550	
	UELZ=++ALSE	ALSE.	4	
		000	_	
	700 CONTINOE		00014580	
၁		•	065+1000	
	IF (FAC)	IF (FACI. of .0.5) 60 TO 800		
	UELZ= - INUF		01941000	
	IF (UEL 1)	0 % 10 % 00	00014620	
	HUD CONTINUE		00014630	
ر.			00014640	



10014930 00015040 00011000 01031000 00011000 00015110 00014870 06841000 00641000 01641000 00014920 09651000 00014950 09651000 01691000 08691000 066\*1000 00051000 01051000 02051000 00015030 00011000 06051000 00151000 0015160 00151000 00014850 00014960 00014880 KI (KOUI) = KSING (KOUT) + NETINC IF (KSAME . F.O.O) RE TURN DO CIOU REL'KSINGK US (K, JNE#) =U1 (K,J) SUBKOULLINE INUN NE I INC=NE I INC-1 UI (K.L) =US (K.L) KSING(L)=KT(K) NO 2200 K=1 .N UO 2300 L=1+J 300 K=1 . N JNE W= J+NE I INC H(T) =HNFM(T) HNEW (3) =0. CONTINUE CON I INUE CONTINUE CON I INUE CUNT IMUE CONTINUE KSAME =() J=JNEW AE TURIN RE. TORN EN

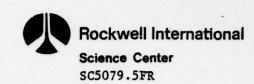
IMIS SUBMOUTTHE COMPUTES THE LUCAL TRUNCALION ERROR OF THE CENTERED-FILLOUDISTAGESCHEME. THE TRIFFICER VARIABLE "# 17P-E ## INDICATES THE FULLOWING 00015150 00014750 09941000 00014680 0014110 00014720 00014760 00141000 00014800 00014810 00014820 00014830 00014840 00014670 06941900 00241000 00014730 00014740 0014780 062 + 1000 IF (IMNEW (L. NETINC-1) +H(L)) . LE. HMAX) 60 TO 825 HINE W (L+NE | INC-1) =HINEW (NE TINC+1-1)+H(L) IF ( (L+NE | INC+1) . 61. JMAX) 60 19 2500 US (K+L+NE I INC.) =UI (K+L) HNEW (L+NE I INC) =H(L) DU HSO K=1.N פה נה וחניי 60 TO HUC ULL 1=UFLZ リヒししょうだして CONTINUE CONTINUE KEXCEU=1 CUNI INUE KSAME = 1 C DELETION 2260 2500 かいの 2100 2300 858 950 1000 2000 U

25........

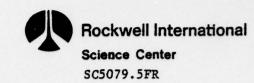


00171100		0015100	151	152	521	526	00015230	524	00015250	00315260	00015270	00015280	529	00015300	700	5.6	00015340	535	536	00015370	-	00015390	00015400	00015410	00015420	00015430	00015440	001000	00015470	U.	00015490	00015500	01921000	00015520	00015530	00012540	00015550	00015560	0155100	00015580	00015590	00951000	01951000	00015620	00015630	00015640	00012650	00015660
	11	_	Y		INTEGE	COMMON ANT SHY HALL ALL ALL ALL	/PARMA/ N. N.	/PARMS/	CUMMUN /NF II/ 1YPE, NSINGK+KSING(1), L. P (6), U(6), H(6) 1 (6)	CUMMON /SETUP/ UH(4) DHX(1) OFF (4) A ( 14)		IF (IYPE) 100, 200, 300	100 CONTINUE	1 Few delination of the contract of the contra	CELL BOUNDARY POINT	A1=-H(1)/2.	A2=-A1	A3=A2+H(L+1)	A4=A3+H(L+2)	A5=A4+H(L+3)		#I_	[/=[+1	L3=L+2	[+=f+3	L5=L+4		See Con India		INTEHNAL POINT		IF (L.E.y. (KSING (KSINGK)-2)) 60 10 250		AI=-H(L-1)-H(L)/2.	AZ=-H(L)//.	A3=H(L)/2.	A4=A3+H(L+1)	A5=A4+H(L+2)		L =L-1	T5-1	L3=L+1	L4=L+7	L5=L+.3		00 10 400	250 CONTINUE	

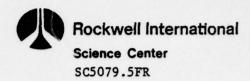
	00015680
A1=H(L)/2.+H(L+1)	_
A2=H(L)/2.	_
A3=-A2	-
A4=A3-H(L-1)	00015720
A5=84-H(L-2)	00015730
	00015740
רויריו	-
L2±L	-
L3=L-1	-
L4=L-2	00015780
L5=L-3	. 06151000
	-
	1581
300 CONTINUE	1582
	00015830
RICHI BUUNDAKY FOIN	1284
	-
AJ=01/2,	00861000
A 2-A 2-K-1	0/851000
(I-1)11-24-CA	00000000
A+=A	06861000
ADEA4=11(L=3)	4 -
	265
רלי=ר	00012930
	00015940
7-7-7	0.0015950
[7=[-3	09651000
	0/651000
400 CON INDE	08651000
	06651000
COMPOSE LOCAL TRUNCALION EARTH IN TWO STEPS	0001000
TRUM INTRI	01091000
	02001000
	0001000
THE PARTY OF THE P	04001000
CALCACT TOWNS	2001000
	**001000
=/3	05001000
-VANUE T (3.41.44.45.0) # A 1844	00016052
+VARIOL I	4001000
9 A 1 8 A 3 8 A 4 + 0	0001000
C3=0.4 (VANDE I (3, 42, 44, A	0001000
-VANDE [ (3.4] , 44.45.00.)	7001000
3141142.A5.U.1U	0001000
-VANUE I (3.41.42.44.0.00	0001000
C4=-6.# (VANDE   (3.42.43.45.00.10.) #41 **4	0001000
1 -VA'4111 [ ( 3 · A   · A 3 · A 5 · 0 · · · · ) # n 2 * * 4	06016072



						X KY - X I Y I	((())-((())				L.		_	ME MEAN THE VECTOR H(L), WHERE		7.M.V	11(1)		H.S.	MARINE CHOOLITE OWN ALLERAM	NUMBER OF STREAMISE STATIONS TO SE MARCHED (THIS EXCLUDE THE STATION	SIREAMWISE MESH, WE MEAN I'ME VECTOR HALL), WHE'ME X(L+1)	CHEALER [HAN ZFRU . WILL X 1] = KA ANI)		FACX, HKS, XA, XB, YA, YD, NA		3	/ KPR1(1)	
DIMENSION X(5)	A(1)=x1 A(2)=x2	X(4)=X3 X(4)=X4	X(5)=X5	VANUE T=1.	L1=L+1	VANDET-VANDETS/X/K/-X/LV		ZOO CONTINOE	:	KE LUNA END	SUHROUTINE YMESH	C Court out hat the court of			ONEATEN THAN CENUS	CUMMON /PARM4/	/MESHI/	KE TURN FAIL	SUBROUTINE AMESH	C SUBBOUITAE IN WHICH IN			C X(L) +HX(L)+ FOR L ONE	CUMMUN / MESHX/		RETURN	SURROUT IN DRAFSH	3	 C SOBROUTINE IN WHICH USER SUPPLIES OWN STREAMAISE STATIONS AT WHICH



M-IN STATION TO HAVE THE SOLUTION PAINTED. NOTE THAT M IS STATCLY RE FUIN



APPENDIX B: 3-D WALL-JET SMALL CROSS FLOW PROGRAM--RUNNING INSTRUCTIONS

The following deck setup will indicate control cards and data cards

(a name list card INPUTS) needed to run the following example:

- (A) Small cross flow CASEW=.TRUE.
- (B) u = 0 at outer edge of jet, C4 = 0.
- (C) Parameter in logarithmic spiral K = 1/3, C1 = 1./3.
- (D) The induced magnitude of induced cross-flow  $K_2 = 1$ , C7 = -1.
- (E) Meshes, initial profile + streamwise output stations are all to be provided by program.
- (F) Streamwise station to be solved to XB = 1.
- (G) Initial mass flux = 1.

## 1. Deck Setup

Job Card

FTN4.

LGO.

7/8/9

Source program

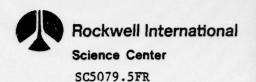
7/8/9

-\$ INPUTS CASEW=.TRUE., C1=.33333333, C4=0., C7=-1.\$

7 Second column

6 / 7 / 8 / 9

For other desired cases, see definitions of the various variables and their options in the listing. The solutions are to be printed on paper



in sequence of streamwise stations. Thus, for any s location, there are eight columns of outputs:

Column 1: index of vertical net points

Column 2: y-vertical net point values, from y = 0 (1 in column 1, at the wall) to y = YB (the last value in column 1, outer edge of jet)

The next six columns have the same convention as column 2:

Column 3: F--Glauert similarity variable

Column 4: DF--the partial derivative  $\partial/\partial(\text{eta})$  F

Column 5: DDF--the partial derivative  $\partial/\partial(\text{eta})$  DF

Column 6: P--the reduced pressure P

Column 7: W--cross-flow velocity

Column 8: DW--the partial derivative 3/3(eta) W

To find out the computed values of (F, DF, DDF, P, W, DW) at y = 0.5, say, we need to look at the horizontal line with the y-value on column 2 to match with y = 0.5 (provided y = 0.5 is a net point), then the third to eighth columns will give the function values of F, DF, DDF, P, W, DW at y = 0.5.

## 2. Type and Configuration of Computer Used in Program Development

- (i) Lawrence Berkeley Laboratory 7600
- (ii) CDC 6600 at Arbor Vitae, Los Angeles, and Sunnyvale

## 3. Estimate of Running Time

16 seconds on CDC 7600

4. Name and Level of Programming Language Used in Program
FORTRAN IV